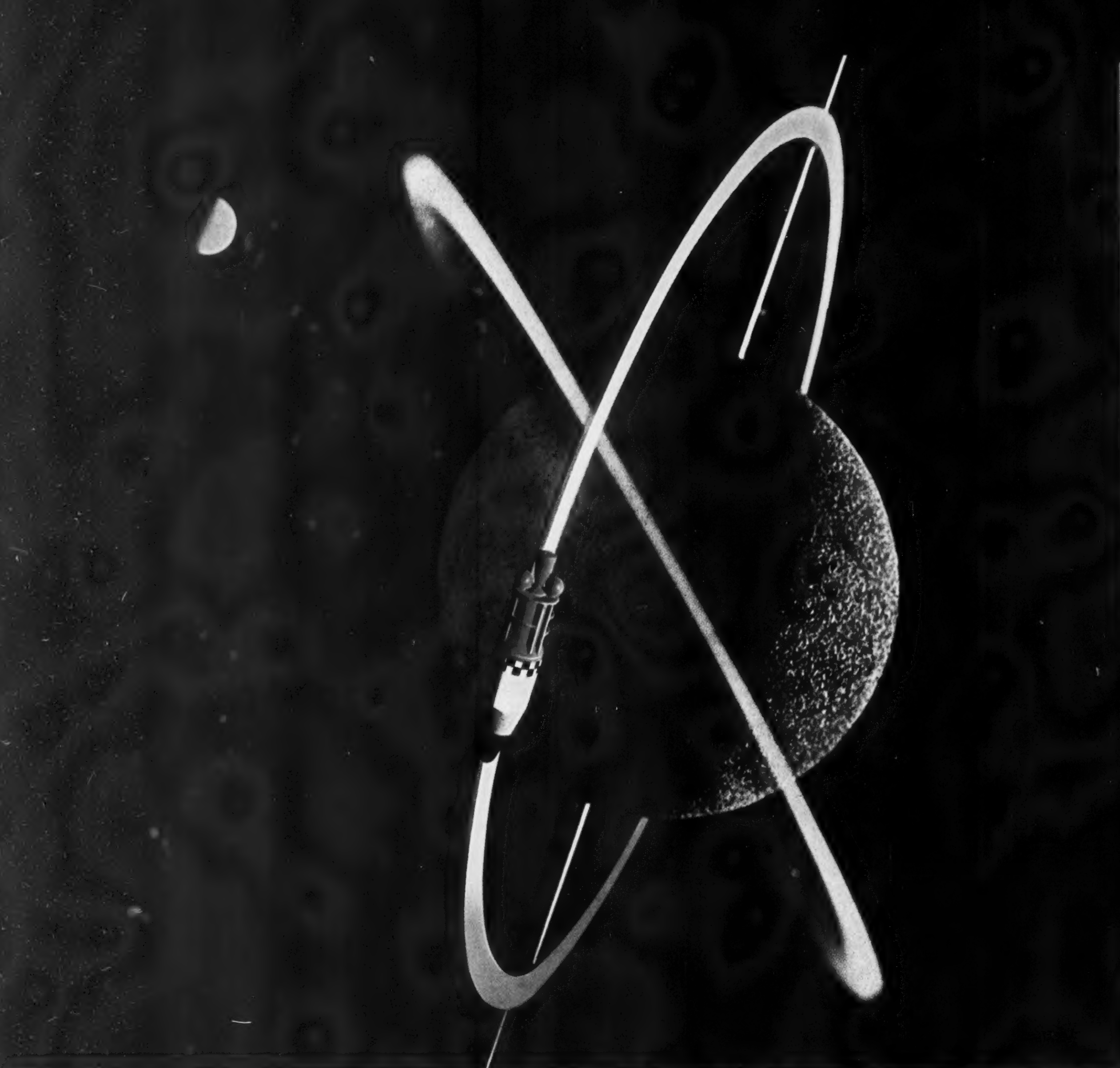
Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

MAY 1960

SPACE ELECTRONIC SYSTEMS

ARS SEMI-ANNUAL MEETING PREVIEW



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Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY INC.

May 1960 volume 5 number 5

EDITORIAL

SPACE ELECTRONICS

FEATURE

ARS SEMI-ANNUAL MEETING

DEPARTMENTS

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Astro notes

SATELLITES

• After a run of indifferent luck with its weather experiments, NASA rang the bell with the Tiros-I cloud-cover satellite. The 270-lb package included two RCA vidicon cameras, magnetic-tape storage equipment, command receiver, 2-watt transmitter capable of reading out 64 pictures in 3.5 min using a bandwidth of 62.5 kc, and an imposing system of solar cells. Despite a malfunction of the clock programming device for the narrow-angle vidicon (images 80 miles on a side with 500 lines per frame), the satellite produced approximately 2000 pictures in its first week aloft, most being supplied by the wide-angle vidicon (images 800 miles on a side and 500 lines per frame). NASA's Abe Silverstein estimated that Tiros I should operate three months.

• The excellence of the Tiros pictures led many to speculate on its reconnaissance capability. NASA finally held a press conference and showed off all the pictures it had to prove that no object of military significance could be seen, not even cities.

• An interesting feature of the solar-powered satellite's operation is the fact that its spin axis will deviate from the plane of its orbit. The narrow-angle camera thus lost sight of the earth entirely after 15 days, and the images obtained by the wide-angle (100 deg) vidicon will gradually contract to a narrow sliver as the spin axis of the satellite reaches a 90-deg angle with the plane of the orbit about 30 days after launching. As the angle approaches 180 deg, the wide-angle camera will record increasing portions of the earth and the narrow-angle lens will once again record cloud-cover data.

• Third-stage ignition failure stymied the NASA attempt to put a 23-lb package of radiation detectors into a highly-elliptical orbit with the Juno II. The package was to go into a 17-hr orbit with a perigee of 200 miles and an apogee of 33,000 miles, so that it could obtain a complete profile of the earth's radiation belts. NASA's present Juno II program still includes one backup shot for a satellite of this kind.

• The Navy's second attempt to orbit a Transit navigation satellite was successful April 13. The AF proceeded to launch the 265-lb experimental Transit with a new two-stage vehicle called Thor-Able-Star. The "Able-Star" portion of the vehicle measures almost 15 ft in length and 5 ft in diam and has a total burning time of 300 sec, compared with about 100 sec for the Able stages previously used in space launchings. Able-Star's thrust was put at 7900 lb, compared with 7700 lb for the Able. The new rocket stage, built by Aerojet, employs eight small nozzles to emit pressurized nitrogen gas during coasting periods to control attitude prior to final orbital injection. On April 14, the Navy announced it would attempt to orbit a second Transit late this spring.

• NASA is planning a 350-lb solar observatory satellite for a launch by a Thor-Delta rocket in the spring of 1961. The package will be equipped with X-ray spectrographs sensitive to 10 Å, photomultipliers to detect ultraviolet, and several secondary experiments, including gamma radiation and neutron albedo. The satellite will employ a flywheel arrangement and gas jets to keep it pointed at the sun with an accuracy of 1 min of arc.

• NASA is also planning a 150-lb "flashing-light" satellite, which would be put in an 800–1000 mile orbit. Emitting 1-millisec pulses of light every 2 min during its nightside passages, the satellite will be visible to the naked eye at 1000 miles, giving about the brightness as a third- or fourth-magnitude star. The satellite will incorporate solar cells, tracking transmitters, a command receiver to trigger pulses of twice the normal intensity, and optical corner cubes to reflect the beams of searchlights on the ground.

PIONEER V

• NASA's 94.8-lb space probe, Pioneer V, finished the first month of its long, lonely journey with its equipment in good order. At 3.5 million miles from the earth, its 5-watt signals were still coming in distinctly to tracking stations at South Point, Hawaii (60-foot dish), and Jodrell Bank, England (250-ft dish). It was clear that Hawaii would soon lose the ability to command the planetoid; but the antenna at Jodrell Bank was expected to have no trouble at great distances.

• NASA is determined to stick to the 5-watt transmitter until mid-May or longer before it resorts to the 150-watt transmitter. Because of its higher power consumption and its great output of heat, the 150-watt transmitter has a greater probability of failure than the 5-watt system; and NASA doesn't want to command it until absolutely necessary. "We don't even know if the 150-watter is working," a NASA engineer confided wryly. "It wasn't checked out at the Cape because there was some fear that the radio-frequency energy might set off some of the squibs in the third-stage pyrotechnics."

• Pioneer V has already obtained important information with its spin-coil magnetometer, according to Space Technology Laboratories, which designed the payload. For instance, it encountered magnetic fluxes of 10 to 100 micro-gauss at 5 to 7 earth radii. This appears to verify the existence of the Sturmer current rings. (The Russians reported the current rings after the Lunik-I flight, and they may have been detected by Pioneer I late in 1958.) The probe also reported a disturbed region in the earth's magnetic field at 10-14 earth radii. This disturbed region is apparently caused by a constant "solar wind" of protons interacting with the earth's field.

SPACE TECHNOLOGY

• The AF Wright Air Development Div. previously WADC is developing a "space heliograph" which may be able to transmit up to 10 words per minute even from such a remote and "noisy" environment as the full moon. It would consist of a mirror of about 1 square meter in area plus a mechanical shutter or polarizing cell to modulate the transmitting light beam. Its chief advantage would be energy conversion efficiency; it can utilize 50–60 percent of the incident sunlight, compared with only about 1 percent for a solar-powered transmitter like the one in Pioneer V.

• NASA contract awards were expected in April for the airframe of the second stage of the C-1 version

of the Saturn vehicle and for the 200,000-lb-thrust lox-hydrogen engine for the second stage of the C-2 Saturn. As now planned, C-1 will have four Centaur engines totaling about 80,000-lb thrust in the second stage and two Centaur engines as the third stage. The C-2 Saturn will be a four-stage vehicle like the C-1 except for a second stage powered by two of the 200,000-lb-thrust engines. Cost for the C-1 development and testflight program (10 rockets through March 1964) was put at $850 million by NASA's Deputy Administrator Hugh Dryden.

• NASA has dropped the "bustle" from the shape of its lunar orbiting paddlewheel packages as a result of studies conducted since the first Atlas-Able moonshot failed last Thanksgiving Day. The agency found that the aerodynamic loads on the fairing peaked between two of the speeds measured during the tests and that the upper stages tore loose from the Atlas booster at this critical point. To ease the load, NASA has switched the package from a sphere to a more cylindrical shape, thus eliminating most of the waist in the protective fairing.

SPACE WEAPONS

• The Weapons Guidance Laboratory of WADD has dreamed up a rip-snorter of a space weapon which it calls ADOS—Astronautical Defensive-Offensive System. It may be the first serious—and feasible—proposal to employ particle radiation for long-range combat in space.

• As visualized by its originator, Roman Szpur, the ADOS vehicle would be shaped like a lollipop. At the end of the stick would be a nuclear reactor for power; the sphere itself would contain the fire-control system and would be encircled by a ring movable on two axes, so that an orifice could be pointed in any specified direction. The ring itself would be a synchrotron or cyclotron capable of accelerating bursts of protons or electrons to high energies, while neutrons could be emitted directly from a slot built into the reactor.

• "Radiation weapons begin to smell beautifully outside the atmosphere," Dr. Szpur commented. Beams of particles can be focused precisely and transmitted great distances without absorption or scattering in the vacuum of space, he explained. Furthermore, the power requirements are not beyond reach. "Even two kilowatts focused on one-tenth of a centimeter can do a lot of damage," he said.

• Although it is far too early to think about hardware development, the temptation is irresistable to speculate about the possibilities of the system. One can visualize a screen of ADOS vehicles circling the earth in "guardian" orbits, ready to pounce on hostile targets upon command from the ground. Missile warheads might be "cooked off" by ADOS neutron beams, while enemy spacecraft with delicate electronic equipment or human passengers could be disabled with the highly ionizing bursts of charged particles from the ADOS accelerators.

DEFENSE SHIFTS

• In a series of sharp program revisions, the AF has wiped out the 400-mile-range Bomarc-B air defense missiles and their associated Super Sage control centers on the West Coast. Bomarc-B squadrons will be eliminated at Paine AFB, Wash., Adair AFB, Ore., Travis AFB, Calif., and Vandenberg AFB, Calif. The USAF insisted the action won't affect the Canadian plan to deploy the Bomarc-B missile and that the American program continues to provide for the necessary Sage control and direction centers in Canada to operate the weapon.

• The airmen said the Sage-Bomarc phase of the air defense program has been slipping in time and that it probably could not be completed until 1966 when the main threat should be ballistic missiles. In order to meet better the principal Soviet attack threat in the next year or so, the AF said, it will put greater emphasis on the current Century series of interceptors, including a better radar, a new fire control system, and the Gar-11 missile with a small nuclear warhead. It also will continue development of the long-range pulse Doppler radar and the 25-mile-range Gar-9 missile planned for the defunct F-108; these may be in the North American A3J Vigilante in case the AF decides to buy this Mach-2 aircraft for the Air Defense Command.

• The AF stepped up its program to build hardened Atlas pads. It announced that the last six Atlas squadrons would receive three additional missiles each during 1962. It also announced that more effort will be devoted to the Ballistic Missile Early Warning System and the Midas infrared warning satellites. The initial BMEWS site will go into operation this fall at Thule, Greenland, while two more sites at Clear, Alaska, and Flyingdales, England, will be accelerated.

• The Defense Department has assumed close control over all military test ranges, tracking stations, and ground environment facilities in a reorganization which will bring Maj. Gen. Donald N. Yates, USAF, from his present command at the Atlantic Missile Test Center to an office in the Pentagon. He will become Deputy Director of Defense Research and Engineering for Ranges and Space Ground Support, while Alvin G. Waggoner will be Assistant Director. Both will report to Herbert F. York, Director of R&E. The new office will maintain an inventory of all range instrumentation, tracking facilities and test equipment, and it will stay abreast of long-range schedules to employ these facilities. It will advise Dr. York on all plans for new facilities, serve as a focal point to coordinate NASA and military range requirements and, hopefully, help eliminate range squabbles between the services.

MISSILES

• The AF will put its first Minuteman "pilot train" on the tracks this summer. Although lacking missiles, the pilot train will identify requirements for the later operational trains—particularly requirements for communications linking roving trains with the headquarters of the Strategic Air Command. The railroad brotherhoods have promised to man the missile trains regardless of strikes, so it appears likely that the trains will be operated by civilian crews while the airmen work the missiles.

• The total railroad force of Minuteman ICBM's is 250, with another 550 earmarked for installation in underground silos hardened to more than 100 psi. The AF announced the selection of Malmstrom AFB, Great Falls, Mont., as the site for the first three squadrons to be operational in 1963. The first railroad Minuteman missiles should become operational a year later in trains of two to five weapons each.

• The Navy formally announced its interest in the Typhon shipboard air defense missile system with the award of a $38,500,000 contract to Westinghouse Electric Co. to commence development of the long-range-radar portion of the system. The Typhon concept includes both a Super-Tartar for medium range

and a Super-Talos for long range. The system is to have a search, detection, and track range of 200 miles and a kill range of 100 miles.

• Convair Div. of General Dynamics won the Army's competition for development of the Mauler air defense missile and was awarded a $5,500,000 contract to cover costs for the first year of work. Mauler will be a solid-propellant radar-guided missile capable of being installed in "batteries" in a tracked vehicle and of being operated by a three-man crew. It is designed chiefly for protection of motorized columns, and is therefore larger and of greater range than the heat-seeking Red-Eye, which Convair is developing for infantry units.

• Martin-Orlando received a Navy contract to develop a fifth version of the Bullpup air-to-surface missile. Called Bullpup B, the new weapon is to have "improved capabilities" but these were not disclosed. Presumably they will take advantage of the larger warheads and more sophisticated guidance techniques which the AF wants in its Bullpup weapons—e.g., a television guidance system which will permit the pilot of the launching aircraft to break away as soon as the missile releases, yet continue to control it through a TV screen in his cockpit. The present radio command system requires the pilot to follow the Bullpup until it strikes, and therefore is limited to conventional warheads.

• The Administration approved a Navy proposal to undertake advance procurement of reactor components for nine instead of three more Polaris submarines in fiscal 1961, and it may seek formal authorization and construction funds for the vessels if the Navy is able to prove operational readiness of the missile this summer. Recently, the Navy dedicated its Polaris assembly and storage depot at Charleston, S.C., and said it would outfit the George Washington and Patrick Henry with 16 weapons each by year's end.

• The first five Polaris submarines will receive missiles of 1200 n. mi. range, according to Adm. William F. Raborn. The sixth submarine—the Ethan Allan—will receive the first 1500-n. mi. missiles. Flight tests will commence this fall with installation planned for 1962. For the more distant future, Adm. Raborn wants to develop a Polaris of 2500 n. mi. range—which would give the submarines an additional 9 million cubic miles of ocean to hide in.

• In the meantime, Polaris passed its first reported success in an underwater launching with subsequent ignition of a test motor. The test was made by the Navy at its underwater range off San Clemente Island, Calif. The missile rose from a depth of about 200 ft and went into free flight under power for a short distance. Termed a success in every respect by the Navy, this test should move Polaris to the stage of underwater firings from a vessel.

NUCLEAR PROJECTS

• NASA selected Aerojet-General to develop the turbomachinery and related equipment of the 30-kw Snap-8 system currently under development by the AEC. The initial system should have a weight of about 1500 lb, including reactor and shielding, and will be the power source for the first electrical propulsion system for a U.S. spacecraft. NASA was reviewing proposals last month on an arc-jet motor which would use an electrical spark to heat and expand a gas through a nozzle, and is expected soon to request proposals for an ion motor. Both would be tailored to the 30-kw Snap-8 reactor—the arc-jet to raise satellites from near orbits to "stationary" orbits at 22,000 miles and the ion motor for more ambitious interplanetary flights. Both may be ready for flight test in four years.

• The AF is studying a much more powerful nuclear powerplant called Spur—Space Power Unit Reactor. This is a 300-kw reactor operating at a core temperature of 1800 F and a radiator temperature of 1200 F. It would employ three liquid metal loops—sodium, potassium, and lithium. The AF expects to award a design study contract shortly for Spur, but it will be up to the AEC to develop the nuclear reactor part of the system.

• Spur is interesting because it begins to approach the power levels necessary for large manned spacecraft, as opposed to the small, lightly-shielded "snooper" type of vehicles which can be propelled by the lower-powered systems. As an example of the power requirement for a manned spacecraft, NASA has described a 12,600-kw, 58-lb-thrust system which could carry an eight-man expedition to Mars and back.

• AEC has announced that two reactors are in preparation for a Kiwi-A Prime test series this summer. Nearly identical, and identified as Kiwi-A Prime and Kiwi-A3, they resemble Kiwi-A outwardly, and will use the same test cell and other facilities in a variety of experiments aimed at pushing the nuclear rocket program. Kiwi-A3 will be run continuously until the reactor shows damage, in an effort to determine safety margins and performance limits.

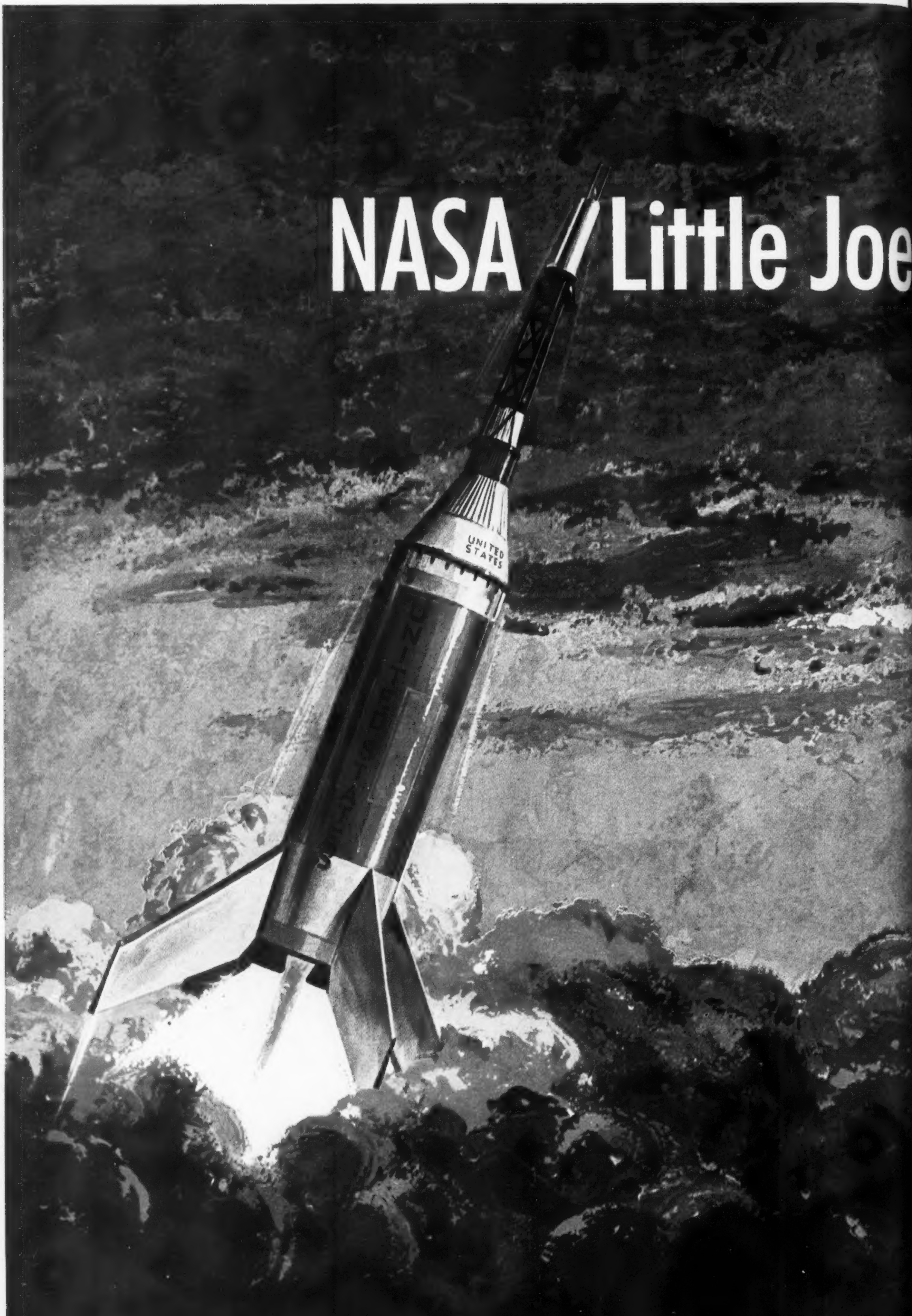
• In addition, a new test cell, scheduled for completion in 1961, is being built at the AEC Nevada test site. This cell will permit more extensive exploratory testing of complete nuclear rocket engines. In the meantime, Kiwi-A has been reassembled without nuclear components and hooked to the test cell at the site for nonnuclear cold-flow experiments preparatory to testing with the two new reactors.

• AEC fusion-research program has passed a historical landmark. "We are now prepared to stake our reputations that we have a thermonuclear reaction," said James L. Tuck of Los Alamos, reporting to Congress on the program. The reaction, achieved in Scylla, took the form of an eggshaped fireball $^{8}/_{10}$ in. in diam, containing about 50 quadrillion deuterons per cc at a temperature of about 13 million C. Reactions have now been sustained for as long as seven-millionths of a second.

• AEC scientists also described prospects for cryogenic electromagnets that would greatly reduce the size and cost of fusion reactors. Example: A cryogenic electromagnet based on refrigerated sodium at 10 K would be 10 ft in diam and 100 ft long, have a power output of about 50 megawatts, and employ a magnet weighing 700 tons. A reactor similar in purpose based on an unrefrigerated copper electromagnet at 300 K would be 45 ft in diam and 330 ft long, generate 5000 megawatts, and employ a 500,000-ton magnet—requiring for its construction some 50 percent of an annual production of copper in the U.S.

• The next goal in fusion research, according to AEC spokesmen, is the attainment of plasmas heated to 50 million C or more. This is expected in a relatively few years. Research is moving fast at Los Alamos, Livermore, Berkeley, Oak Ridge, Princeton, and NRL. The most extensive work is being done with magnetic-mirror generators. The Livermore Astron, a unique piece of equipment involving the

(CONTINUED ON PAGE 12)


NASA / Little Joe
UNITED STATES

rotation of electron streams to form a magnetic sheath, is moving into new areas of research. Astron should go into action in 1961.

• Swedish rocket expert Nils Werner Larsson has stirred up a storm with his revelations about Soviet nuclear-rocket activities. Larsson says a Soviet nuclear engine was in the experimental phase early in 1958, with first tests carried out last year. The propulsion system is said to combine a nuclear engine with a conventional chemical-propellant system, raising the exhaust velocity obtained to twice that of conventional systems.

• Larsson reported that the engine has a thrust of 180,000 kg and exit velocity is 6 km/sec. The propulsion system, he said, is based on a homogeneous reactor using 30 kg of enriched Uranium 235 and 12,970 kg of graphite. Liquid hydrogen is heated to a velocity of 3–4 km/sec, after which it is burned in four conventional combustion chambers (made of a new alloy in East Germany) with lox and another fuel. Combustion duration is said to be 200 sec. The engine, Larsson noted, is scheduled for use in a vehicle 22 meters long and 4.95 meters in diam.

R&D

• Lear's Solid State Physics Lab is building an electroluminescent thermometer-type engine indicator display for the Navy, marking one of the first applications combining electroluminescence and deposited circuitry . . . CBS Labs' Photoscan air recon system has been bought by Navy and AF for tri-services tests . . . Thiokol has successfully track-tested the complete rocket-catapult assembly for the B-58 escape system . . . Bell Aircraft has received a $1.4 million AF contract for development of an insulated double-walled cooled re-entry structure . . .

• Grand Central Rocket has static fired a case-bonded, cast nitrasol propellant motor at an initial temperature of −68 F after repeated temperature cycling between −75 and +165 F—good performance for a high-energy nitrasol . . . Cook Electric has received an AF contract to study aerodynamic deceleration devices at high Mach numbers and high altitudes . . . Chance-Vought's Electronics Div. has developed a twin-gyro controller which can be used instead of reaction jets or inertia wheels to control space vehicle attitude . . . Sperry has reported development of an electron beam five times more powerful than previous beam devices, thus removing one of the basic obstacles to extension of long-range missile guidance radars and anti-missile systems . . .

• A 100,000-lb-thrust rocket engine using boron fuel and a storable oxidizer has demonstrated the best performance ever attained in large-scale tests of storable liquids, Marquardt reports. The tests were part of the WADD-sponsored hyperjet engine development program . . . Aerojet has developed an optical inspection device capable of providing a detailed interior view of the grain bore for solid-rocket motors.

MATERIALS

• Bendix Products Div. has tested a new high-temperature tungsten-base cermet which showed zero throat erosion in a series of sub- and full-scale solid-rocket firings in a large hot aluminized solid-propellant program . . . M & C Nuclear has announced commercial production of uranium, thorium, and other metal foils in thinner gauges and wider strips than have previously been available. Width has been upped from 8 to 12 in. and thickness reduced from 0.001 to 0.0005 in. . . . Sylvania's Metallurgical Div. has received a $356,000 Navy contract for the development of rolled molybdenum alloy sheet for possible use as structural materials for rockets and missiles . . . A new solid-propellant rocket binder combining the high-performance of hydrocarbons with the superior processing and broad performance characteristics of polysulfides has been developed by Thiokol. The new C-12 polymer is now being evaluated for optimum viscosity and molecular linkage . . . Thiokol has also discovered improved methods for producing three new nitrogen-fluoride oxidizers—dinitrogen tetrafluoride, dinitrogen difluoride, and difluoramine—as well as a means for improving the yield of nitrogen trifluoride.

EDUCATION

• One of the most ambitious and potentially far-reaching youth education programs in astronautics makes a formal bow May 7 with the Explorer Scout Science Exposition being held in Los Angeles, Calif. This Exposition, expected to draw a participating audience of some 700 Scouts from the L.A. area, will feature prominent ARS members as speakers—e.g., Howard Seifert, Milton Clauser, William Rogers, and Arthur Kantrowitz—and will have displays provided by the Southern California astronautics industry under the sponsorship of Daniel, Mann, Johnson, and Mendenhall. With the further guidance of the ARS Education Committee and the Southern California Section, and the cooperation of government and industry groups, the L.A. Council of the BSA will follow this introductory exposition with a two-day camperee in June at a missile base and a 40-lecture seminar on the astronautical sciences in the L.A. area during the 1960-61 school year.

INTERNATIONAL NEWS

• U.S.S.R. threw a curve at the UN and its plans to hold an international outer space conference this fall by demanding that a Soviet scientist be given the task of organizing and administering the meeting. It now looks as though the meeting will have to be postponed until next spring.

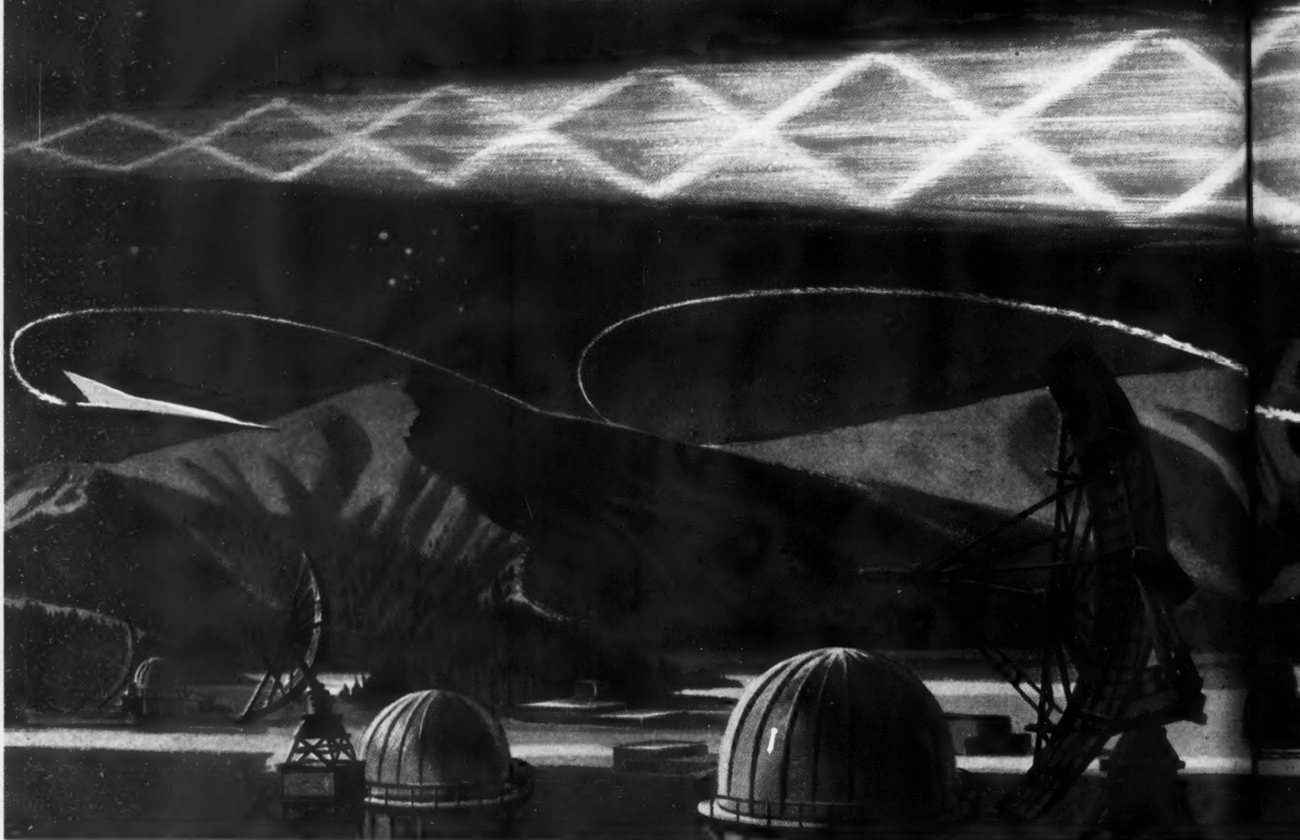
• NASA and the Canadian Defense Research Telecommunications Establishment will carry out a joint study of the ionosphere by means of a sweep frequency topside sounder satellite next year. The project is the first in NASA's program of international cooperation in the space sciences. NASA and British scientists have already reached a tentative agreement under which three British satellites would be launched by U.S. rockets within two to four years, and NASA is also considering the purchase of British Skylark research rockets which would be instrumented here and fired at Woomera.

• A team of scientists and technicians under R. D. F. Boyd has built a unique "flying telescope" at University College, London. Incorporating six photomultipliers and built at a cost of only $1500, the telescope will be used in an early Skylark flight at Woomera to build up TV-type pictures of the sky and measure the intensity of ultraviolet light beyond the earth's atmosphere.

• U.S. and Australia have reached an agreement on long-term cooperation in space exploration. Initial steps will include the building of facilities at Woomera for tracking and interrogating U.S. satellites, and, in particular, Mercury capsules. An 85-ft radar-tracking telescope will be built by the U.S. near Woomera as the first step in the program . . . The U.K. is developing a new AA missile, Tiger Cat, actually a landbased version of the Sea Cat, for Army use.

Marquardt Advanced Nuclear Systems for Air and Space

MARQUARDT EXPANDS WORK ON "PLUTO"



Broadened team effort with University of California's Lawrence Radiation Laboratory aims toward early feasibility demonstration of a nuclear ramjet reactor (Project PLUTO).

A supersonic, low-altitude missile capable of weaving, feinting and dodging unobserved by conventional radar while seeking out selected targets — this is to be the mission of the Air Force's proposed nuclear ramjet-powered vehicle of virtually infinite range.

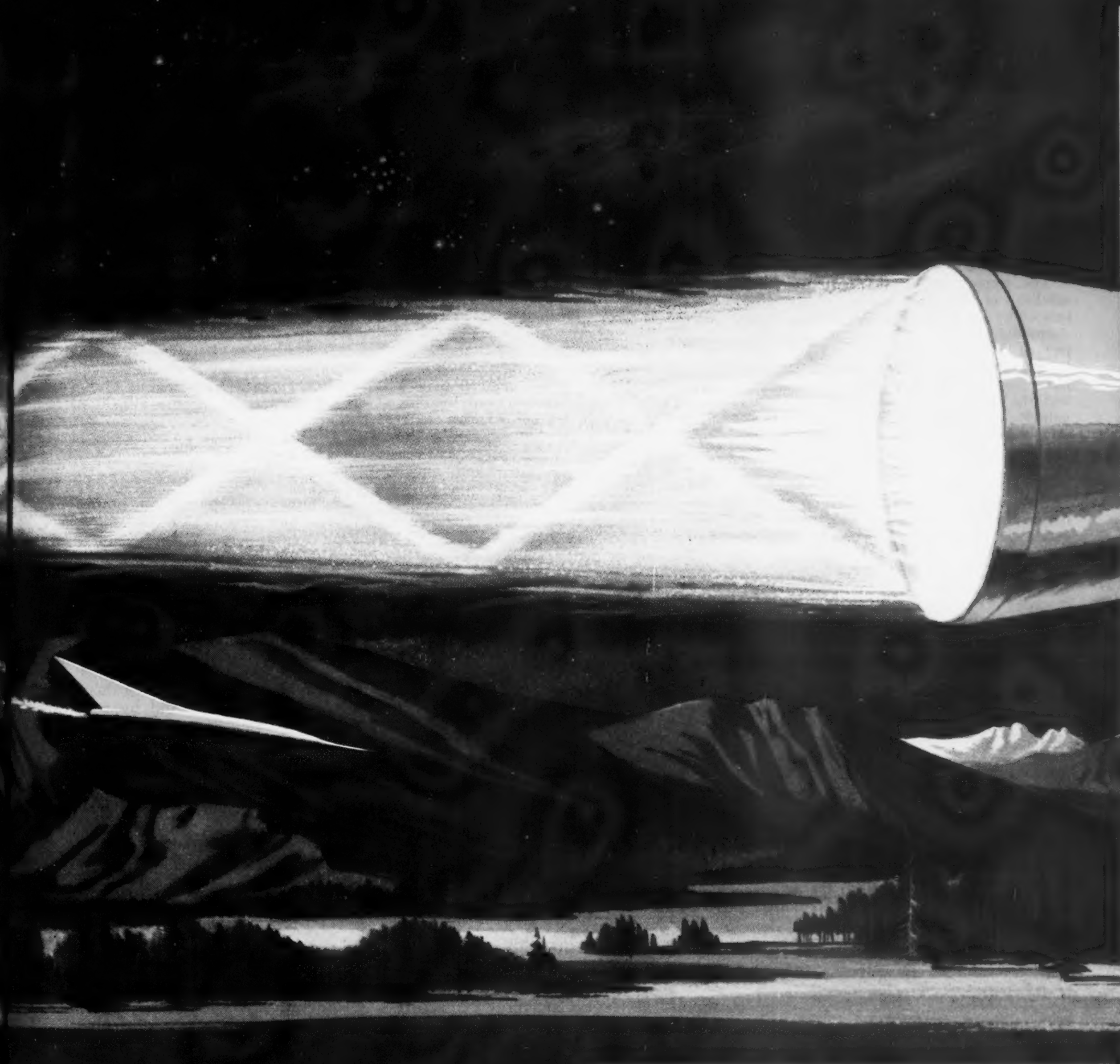
As an integral part of the team which is contributing to this country's all-out race for supremacy in weapons, Marquardt is working with the University of California's Lawrence Radiation Laboratory on the nuclear ramjet program, known as Project PLUTO.

Marquardt's basic PLUTO effort concerns preliminary design of the nuclear ramjet and development of airborne reactor controls and other components for severe temperature and radiation environments. The multi-million dollar program supports a multi-phase corporate effort headed by the Nuclear Systems Division.

Other aspects of Marquardt's PLUTO effort include: support of LRL's feasibility tests on the non-flyable Tory IIA reactor; design and fabrication of significant portions of the reactor's control system, air ducts, flow instrumentation and remotely operated disconnects; fabrication and test of reactor core structural components; architect-engineering on the test air supply system; participation in a supporting program of environmental tests; and preliminary design of test facilities for full-scale power-plant development.

Highlights of the Corporation's other current nuclear programs include: exploration of both military and non-military applications for transportable reactors of advanced design, including their use for space power; development of the engine control system for the G-E nuclear turbojet; research studies of advanced space propulsion devices utilizing nuclear concepts; materials and processes work with molybdenum, other refractory metals and ceramics; and development of original nuclear instrumentation.

For a copy of Marquardt's new "Nuclear Systems" brochure, write to Mr. Aikman Armstrong, Chief Applications Engineer-Nuclear Systems, The Marquardt Corporation, Van Nuys, California.



Mail bag

More on the Moons of Mars

Dear Sir,

The hypothesis on the origin of the satellites of Mars which was recently advanced by Dr. Shklovsky (December 1959 *Astronautics*) has since become the subject of a lively discussion. Arguments both in favor and against the hypothesis have been presented. These mainly deal with the essence of Dr. Shklovsky's theory; namely, that no natural explanation is possible for the low density of these satellites. Apart from this, however, a few arguments were used which were more of an indirect nature. The writers of this letter propose to say a few words about these latter arguments first and then proceed with the main subject of the hypothesis; that is, the low density.

According to the interview, Dr. Shklovsky finds it incomprehensible that the moons Phobos and Deimos move over nearly circular orbits, lying precisely in the equatorial plane, and takes this as evidence that the satellites must be artificial. However, we feel that the circular orbit cannot be taken as an indication of their artificial origin, since many other satellites move in a nearly circular orbit. As far as the fact that they lie in the equatorial plane is concerned, we feel that this argument even supports the opposite theory. From our own experience, we know that satellites in an inclined orbit provide more information and, from a strategic point of view, are of more advantage than those in an equatorial orbit. An orbit over the poles, for instance, would support the theory of artificial origin much more than an equatorial orbit.

The two arguments put forward by Prof. Tombaugh against the Shklovsky hypothesis have been criticized by Prof. Singer, and the writers of this letter couldn't improve on that criticism. Our present knowledge of life processes is so minute that the only safe standpoint is neither to assume nor dismiss the possibility of completely different life-forms with different instincts and rules, but capable of putting a satellite in orbit.

The fact remains however that according to Dr. Shklovsky's calculations, Phobos must have a very low density. Even with Prof. Tombaugh's correction, the density must be of the order of one-hundredth the density of water. Is it really impossible to explain this low density on a natural basis? On this point the writers of this letter have not been convinced at all by Dr. Shklovsky's process of elimination of possibilities. It is, for instance, possible that Phobos consists of a very porous substance, like pumice on earth. Pumice was formed when molten rock with a high gas content under extremely high pressure was suddenly exposed to a very low (atmospheric) pressure. Since Mars itself has had very litle volcanic activity, the two moons must have been formed elsewhere. What is more natural than to assume that they were normal asteroids before they were captured in Mars' gravitational field? This point of view seems to be supported by Prof. Tombaugh's reference to the albedo of asteroids.

The assumption of a porous body leads to a rather startling suggestion concerning the asteroids. If Phobos and Deimos once belonged to the group of asteroids and if they are indeed of a pumice-like nature, then they must at one stage have been under very high pressure. This could only be the case inside a planet with a crust. If this is true, then the asteroids are remnants of such a planet—the missing planet of Bode's rule.

At this stage, the writers of this letter hesitate to carry on; for it is only a small step to mere speculation. Only a catastrophe could break up that planet into thousands of asteroids, some of them with a very low density. And by a similar process of elimination of possibilities, as used by Dr. Shklovsky, the authors arrive at the conclusion that this breakup could have no natural cause. Consequently, this planet was blown up (perhaps accidentally?) by intelligent beings, killing themselves in the process. Thus indirectly the low density of the Martian moons does indicate the existence of intelligent life in the past.

Jan L. Abels
and Kenneth Simons
Lachute, Quebec, Canada.

We Can Explain

Gentlemen:

In the December 1959 issue of *Astronautics*, the final paragraph of the article titled "NASA—Age one" reads:

"Despite its tribute to NASA's organizational effort and a broad range of interesting laboratory work, the Inspection could leave you with the impression that a historical preoccupation with aerodynamics may be inhibiting progress on major space systems.—J.N."

In the same issue, the final paragraph of the article titled "JPL's new hypersonic wind tunnel" reads:

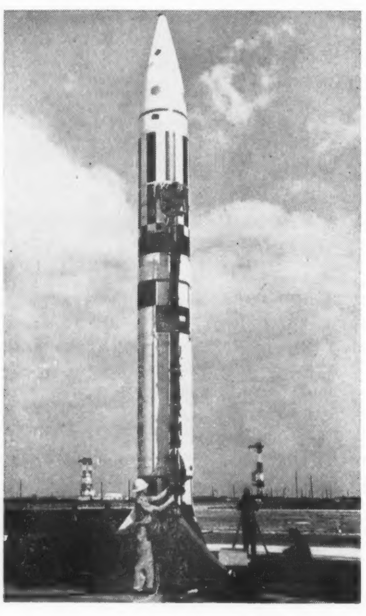
"Altogether, the new hypersonic wind tunnel promises to keep JPL prominent in aerodynamics, and stands as a tribute to the foresight and institutional strength of Galcit and its pioneers.—J.N."

Consistency, thy initials are certainly *not* J.N.!

David E. Reese Jr.
Palo Alto, Calif.

There was no intention to appear inconsistent here, nor to imply that aerodynamic studies are not important for supporting space-vehicle development. The only intimation was that the NASA Inspection could perhaps have shown more of the agency's planning and expectations for advanced propulsion and large payloads for space exploration.—Editor.

Pershing's First Flight Test Successful

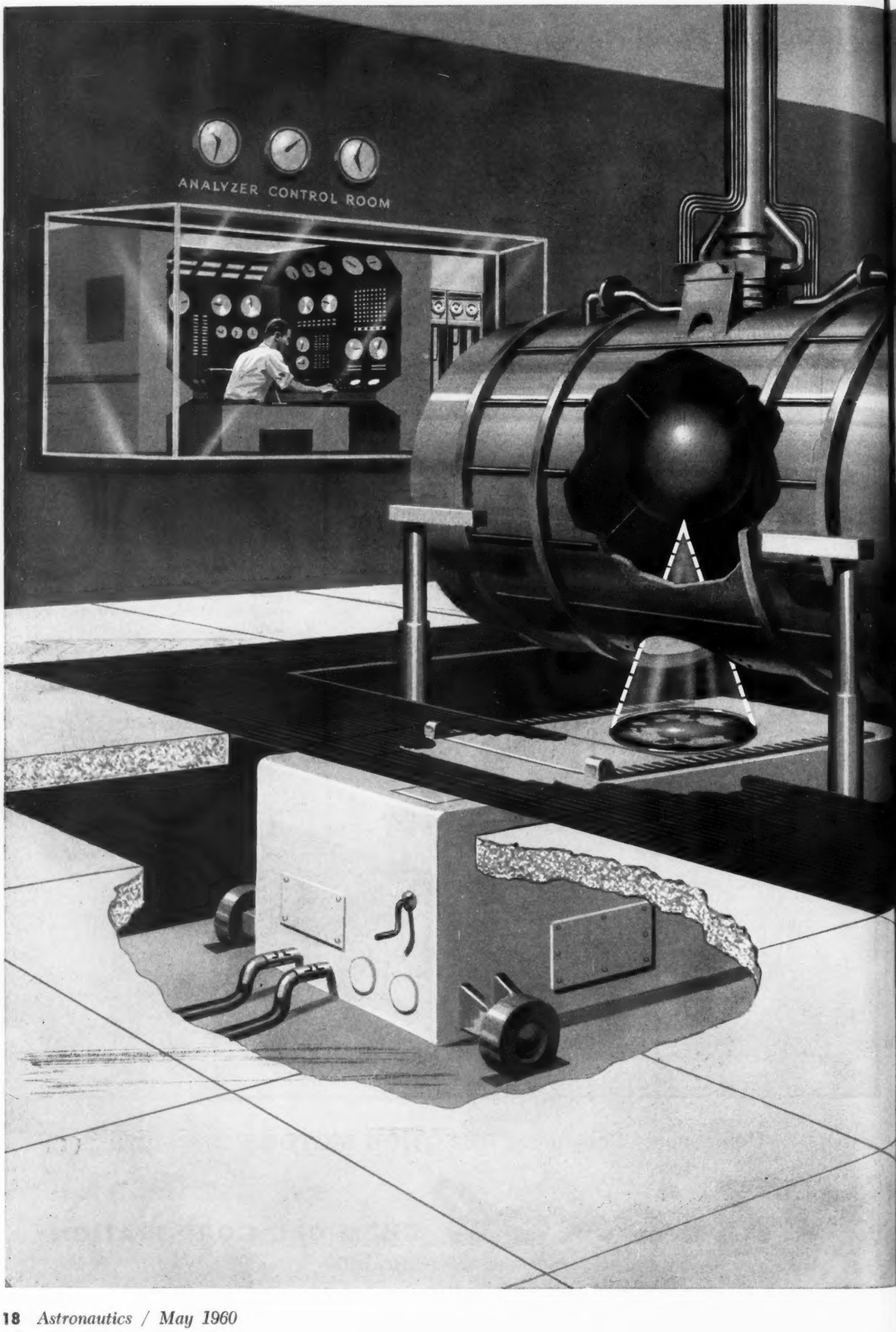


Pershing is shown in launch position on transporter-erector-launcher which makes it "shoot- and-scram" missile.

The versatile Pershing missile—designed to hit targets at ranges 20 to 450 miles—successfully got off the ground at Cape Canaveral in its first attempt on February 25, bringing jubilation to the Army and The Martin Co., the prime contractor. The dummy second stage carried weight equivalent to the fuel load that will be aboard on later firings.

When operational, the "shoot-and-scram" missile will be transported to a firing site by a new type transporter-erector-launcher, positioned and fired in minutes, and then moved out again. Its "built-in" inertial guidance system is being tailored to resist enemy jamming. The Pershing will eventually replace the Redstone.

The Army has allocated $118 million during fiscal 1960 to Martin for continued R&D of the Pershing system. Working with Martin are Eclipse-Pioneer Div. of Bendix, responsible for the guidance system; Thiokol Chemical, first- and second-stage propulsion systems; Bulova R&D Lab., adaption kits; and Thompson Ramo Wooldridge, transporter-erector-launcher.


ANALYZER CONTROL ROOM

100 minutes in space... at zero altitude!

Honeywell Dynamic Analyzer recreates authentic shoot environment, pinpoints design deficiencies

The Honeywell Dynamic Analyzer will simulate actual flight conditions from sea level to extremely high altitudes which affect performance and reliability of aerospace systems. An integrated test facility, it brings together for the first time most of the conditions and phenomena that cause aerospace system breakdowns.

It will be independent of the weather, the availability of test vehicles and flight variables. And in many cases, the test data will be more reliable and valid than can be attained in flight testing.

Areas of application include: reconnaissance, guidance, power supply, and communication systems. Tests of complex systems which now might require more than a year to accomplish, will be telescoped down to several weeks. It will be possible to determine which operating systems are detracting from overall performance, and to what degree.

The first Dynamic Analyzer was conceived under the direction of the Aerial Reconnaissance Laboratory of the Wright Air Development Division, USAF. There, the fully instrumented analyzer will be housed in its own building. Capabilities include: high vacuum, high and low temperatures; three-directional vibration; roll, pitch and yaw motion; buffeting; rotation; target variations; controlled ground speed; reflected and transmitted signals.

Honeywell was awarded the prime contract to develop and produce the analyzer on the basis of strong research and development capability. If you have problems in analysis, test or simulation, consider Honeywell's broad experience. Telephone or write: Honeywell, Military Products Group, Minneapolis 8, Minn.

Honeywell

Military Products Group

For the record

The month's news in review

March 1—House space committee votes $915,000,000 for NASA in fiscal 1961.

—NASA creates bioastronautics unit, Office of Life Sciences, headed by Clark T. Randt.

—U.K. reports tests at Woomera of Blue Steel, a powered nuclear bomb, and Blue Water, short-range ballistic missile.

March 3—First AF test of Minuteman airframe is success.

March 8—AEC restores $11,000,000 to Project Rover.

March 9—Navy fires Polaris 900 miles in successful test of flight control equipment.

—Army's Nike-Zeus passes flight test.

March 11—U. S. launches Pioneer V—a 94.8-lb artificial planetoid 26-in. in diam carrying five scientific experiments—on its way into a solar orbit.

March 13—Pioneer V transmits radio signals from a distance of more than 409,000 miles, breaking mark of 407,000 miles set by Pioneer IV.

March 15—AFCRC announces that new photography technique, used in 2-yr lunar project, has produced best maps of moon to date.

—Army Redstone ejects miniature TV camera which transmits pictures of its target area.

March 17—NASA reports that Vanguard I orbit is being altered by solar rays.

—X-15 passes stress flight test.

March 18—Princess Margaret of England commands Pioneer V radio, receives answer from 1,040,000 miles 25 sec later.

March 22—AF fires Titan 5000 miles and recovers capsule.

March 23—Juno II radiation-study satellite shot fails.

March 24—AF cuts its request for Bomarc funds from $420,000,000 to $50,000,000.

—Senate approves $23,000,000 supplement for man-in-space program.

—Pioneer V signals received from 2,000,000 miles above earth.

March 25—Polaris shot from underground tube travels 900 miles.

—DOD formally announces high priority for Midas project.

March 26—AF X-15 tests move into second phase.

March 28—Navy orders speedup in Polaris program.

March 29—X-15 undergoes negative gravity and cold soak tests.

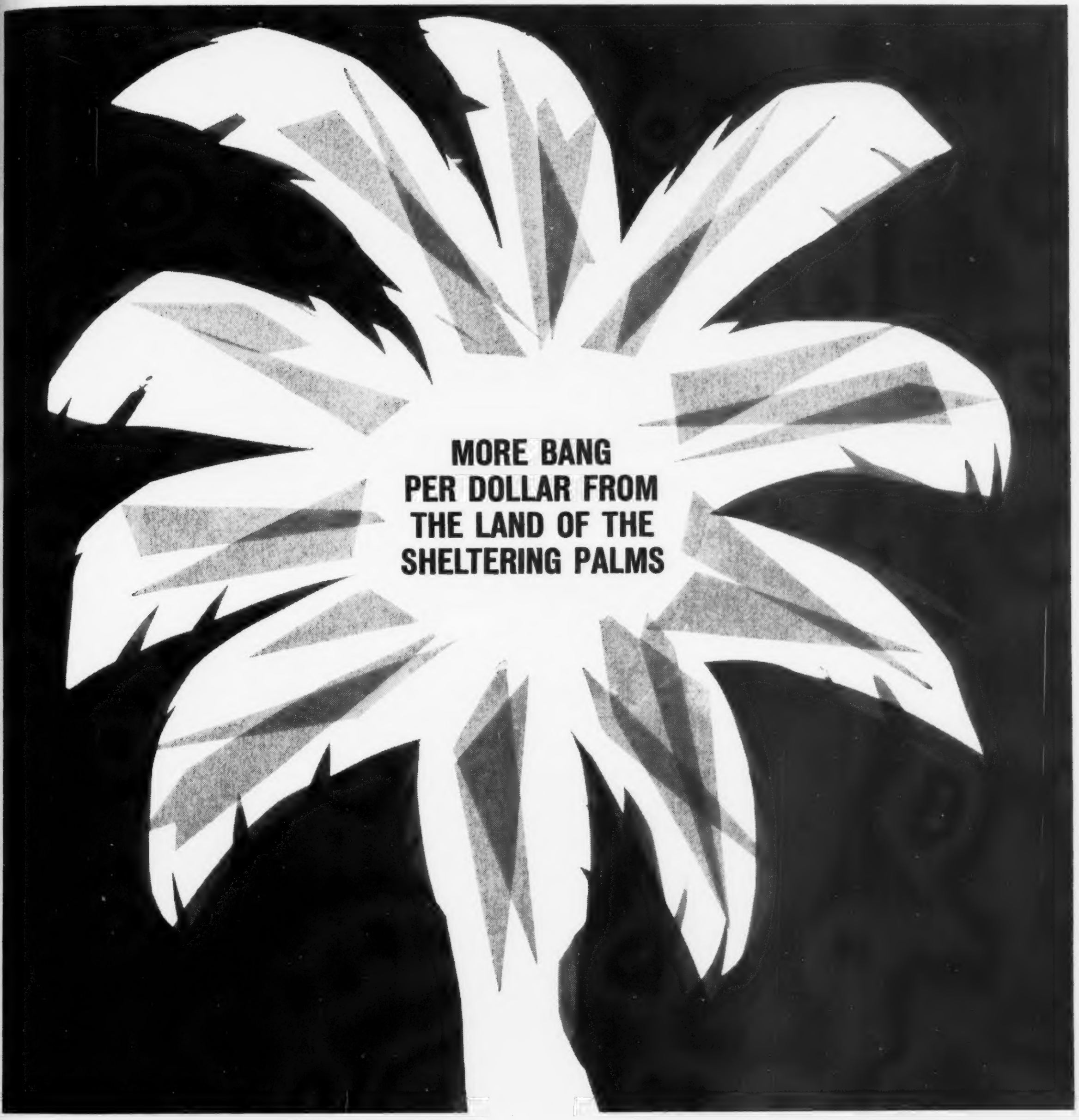
—First Polaris fully guided flight from shipboard falls short of target.

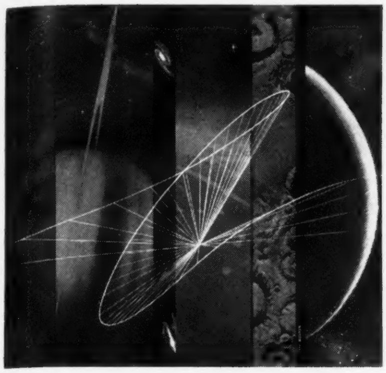
March 30—Wernher von Braun, ABMA chief, says two of Saturn's first-stage engines have passed initial ground test.

Night IR Aerial Photo

This infrared night aerial photo was made over Manhattan by an H.R.B. Singer Reconofax camera, originally developed for the photo reconnaissance lab of Wright-Patterson AFB. The recently declassified photo offers impressive evidence of the capability of IR for reconnaissance purposes.


At 00h00m01s GMT, May 1, 1960, Martin logged its 523,692,000th mile of space flight


MORE BANG
PER DOLLAR FROM
THE LAND OF THE
SHELTERING PALMS



COVER: *A graphic presentation of "Space Electronic Systems," the theme of this issue, by Mel Hunter, indicating some of the areas of exploration for tomorrow's space vehicles. Left to right, the Sun in hydrogen light, Saturn, intergalactic space, Mars, the Moon, and Venus. (Full-cover ASTRO cover plaques, 11 x 12 in., are available from ARS Headquarters at $2.00 each.)*

Astronautics

MAY 1960

Regional Organization for the ARS

Most of us are aware that it is difficult for the members of a large organization to communicate with one another. It is proposed by the ARS Membership Committee that in order to facilitate the flow of information (and to stimulate action!) among the Sections and officers that the members be grouped in geographical regions, each with an elected regional vice-president.

Enthusiastic regional vice-presidents might act in many ways to help the Society. For example—by stimulating the formation of new Sections and the fission of overgrown older ones; by spearheading a strong appeal to students, who will be our future members; by improving public relations for local Chapters; by helping local Sections secure program material and visits from the national officers; and by acting as ambassadors for the Sections to transmit their special problems to the national Board of Directors.

Such regional vice-presidents would have ample scope to demonstrate their administrative talent and skill in delegation. They would function as a staff to the national president, attend Board meetings, and strengthen the efforts of the permanent secretariat. It would be possible for them to promote activities involving small groups of Sections which best serve their unique and disparate needs. Those Sections which had community of interest for geographical reasons (as distinct from national specialist meetings) might have regional meetings under the aegis of the appropriate vice-president.

The Membership Committee suggests that a beginning be made with three regions—Pacific, Central, and Atlantic—with the possibility that these may be further subdivided in the future. It is further proposed that the vice-presidents representing these regions be elected next fall along with the other officers. As President, I invite comment and welcome suggestions from the membership concerning this proposal. Will you let me know your feelings?

Howard S. Seifert
President, American Rocket Society

Telebit—An integrated space navigation and communication system

An outgrowth of the STL Explorer satellite and Pioneer space probe developments, Telebit integrates tracking, command, and telemetry functions in a flexible system tailored for space exploration

By George E. Mueller

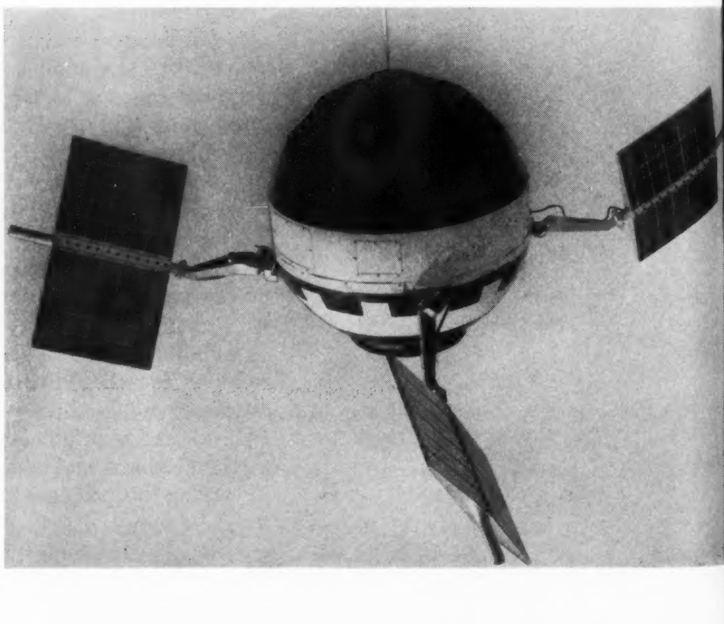
SPACE TECHNOLOGY LABORATORIES, INC., LOS ANGELES, CALIF.

THE GOAL of the Explorer VI satellite, the 143-lb paddlewheel orbited Aug. 7, 1959, was twofold. Most importantly, it served to study the space environment about earth. But it also served as a test vehicle to evaluate techniques for ambitious interplanetary space probes, such as Pioneer V, launched into heliocentric orbit March 11.

One of the principal systems tested by Explorer VI was the space navigation and communication system—Telebit, as it has been dubbed. This system, evolved from Pioneer I of 1958, performs three functions: Telemetry, tracking, and command. As we discuss the Telebit system here, we will give particular attention to the integration of these essential functions into one system.

A fundamental requirement for space exploration is the need to track the vehicle in space. Of almost equal importance are the needs to receive telemetered measurements and to control the opera-

George E. Mueller is vice-president of STL and associate director of its Research and Development Div., where one of his many concerns has been the Telebit system and its applications. The background to his 20 some years of research and engineering work include a B.S. in electrical engineering from the Missouri School of Mines, an M.S. in electrical engineering from Purdue, graduate work in physics at Princeton, and a Ph.D. in physics from Ohio State Univ., where he served as a professor of electrical engineering for 10 years. More recently, Dr. Mueller was a consultant to the Ramo-Wooldridge Corp. The author of numerous technical publications, Dr. Mueller also has six patents in the electron-tube and antenna fields.



Explorer VI Measurements

1. Proportional Counter, high energy counts
2. Proportional Counter, low energy counts
3. Micrometeorite Counts
4. Geiger-Mueller Tube
5. Ionization Chamber
6. Scintillation Counter
7. Magnetometer Amplitude
8. Magnetometer Phase
9. VLF Signal
10. Paddle Outboard Front Temperature
11. Paddle Outboard Back Temperature
12. Paddle Inboard Front Temperature
13. Shell Temperature: Forward Spin Axis
14. Shell Temperature: Equator
15. Shell Temperature: Lower Structure
16. Test Solar Cell (without glass plate) Temperature
17. Test Solar Cell Voltage
18. Solar Cell Current Monitor
19. Battery Voltage
20. Transmitter and Heat Sink Temperature
21. Converter and Heat Sink Temperature
22. Receiver Phase Error
23. Battery Temperature
24. Test Temperature Control Disk Angle

Format for Explorer VI Telebit Communications

Measurement	Word No.	Bit Number											
		1	2	3	4	5	6	7	8	9	10	11	12
Frame synchronization	0	0	0	0	0	0	0	0	0	0	0	0	0
Proportional counter, high	1	0	1	512	256	128	64	32	16	8	4	2	1
Proportional counter, low	2	0	1	512	256	128	64	32	16	8	4	2	1
Micrometeorite	3	0	1	4	2 High Momentum	1	64	32	16	8 Low	4 Momentum	2	1
Geiger-Mueller counter	4	0	1	512	256	128	64	32	16	8	4	2	1
Ionization chamber	5	0	1	512	256	128	64	32	16	8	4	2	1
Scintillation counter	6	0	1	512	256	128	64	32	16	8	4	2	1
Search-coil magnetometer	7	0	1	32	16	8 Amplitude	4	2	1	8	4 Phase	2	1
Flux-gate magnetometer	8	0	1	32	16	8 Data	4	2	1	8	4 Range	2	1
VLF signal	9	0	1	32	16	8 Data	4	2	1	0	0 Unused	0	0
Subcommutated	10	0	1	32	16	8	4	2	1	8	4 Segment Identification	2	1

Note: The appearance of a decimal value in this table indicates the value a "1" has for that bit number. If, for example, word 1 read 011000001000 its value would be 520 (512 + 8).

tion of the equipment. Normally, these functions have been separated in missiles and space vehicles, one system being used for guidance, another for telemetry, and a third for tracking. Explorer I, for example, carried transmitters at 108 and 108.03 mc, one unmodulated for tracking and the other modulated for telemetry. Sputniks I and II carried two transmitters at 20 and 40 mc. Every ballistic missile launched from Cape Canaveral is bristling with separate systems for the performance of separate functions.

Certain critical differences between space probes and ballistic missiles show that it is possible to integrate these systems into a single unit and that it is quite desirable to do so.

For example, a ballistic-missile control system can operate only during the few minutes that the propulsion system operates. During these minutes, the missile must be guided into a trajectory accurately enough to pinpoint a target thousands of miles away. For a space vehicle, however, the final guidance corrections may not need to be made until hours or days or even weeks after launch. In this case, we can guide (CONTINUED ON PAGE 88)

Principals in the most recent experiment with the Telebit communication and guidance system—left, Pioneer V, the probe launched March 11 into heliocentric orbit between Earth and Venus, and right, the Kaena Point tracking station in Hawaii, one of several which tracked the second U.S. artificial planet.

How good is the Lunik III photography?

Selection of full-moon lighting indicates objective was to record maximum area without particular regard to quality . . . Ground resolution, estimated from close study of the photos, is about 30 miles

By Merton E. Davies

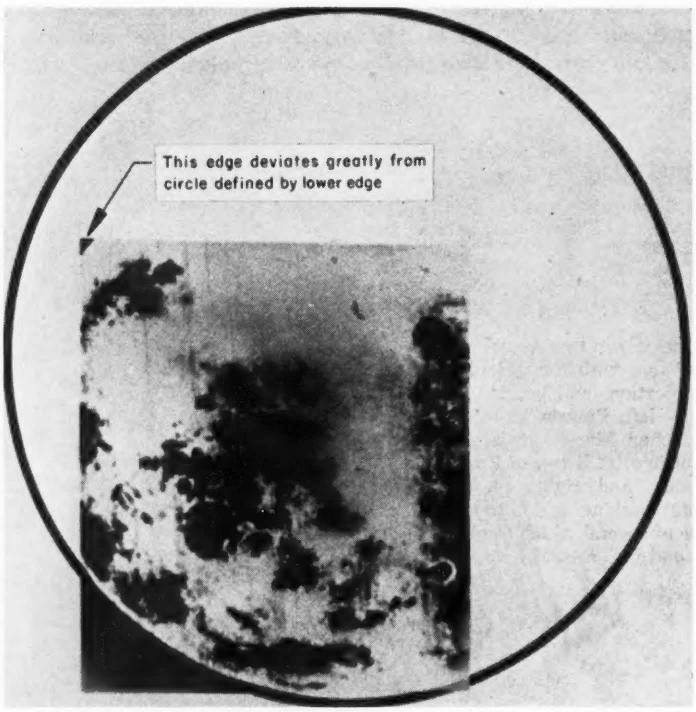
THE RAND CORP., SANTA MONICA, CALIF.

IN A PAPER presented at the 10th International Astronautical Congress in London last year, the author discussed a photographic system for obtaining high-quality pictures of the moon. Included was a comparison of the surface detail yielded by astronomical lunar photography with that afforded by conventional aerial photography. The release of Soviet pictures of the back side of the moon taken from Lunik III affords an opportunity to compare these photos with conventional, earth-originated photographs of the front side.

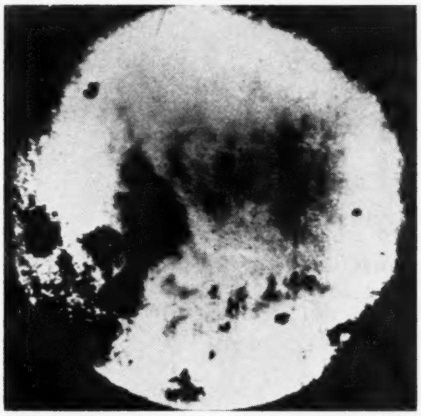
According to the Soviet report, the Lunik vehicle was stabilized when it passed between the sun and the moon so that the optical

Merton E. Davies, a reconnaissance-systems engineer at Rand, is currently working in the Pentagon in Washington, D.C., as a member of Rand's liaison staff with the Air Force. Previously he was stationed in Santa Monica, and participated in studies of reconnaissance systems, with a view to future military needs. After receiving an A.B. in mathematics from Stanford Univ. in 1938, he spent seven years with Douglas Aircraft, where he contributed to the development of mathematical lofting techniques for the design of aircraft, and then, in 1947, joined Rand to take part in its missile and satellite research activities. Davies is a member of ARS and the American Society of Photogrammetry. In 1958, he was a member of the air surveillance group at the Surprise Attack Conference at Geneva.

Detail of Lunik III picture, indicating deviation from circle possibly resulting from error in re-assembly of line scan data.



Lunik III Picture



30-Mile Resolution

10-Mile Resolution

70-Mile Resolution

Comparison of Lunik III photograph with pictures of front side of moon reproduced at different ground resolutions.

system was pointed at the moon, and then the camera was set in operation. The pictures were recorded on 35-mm film, processed automatically, and the pictures then transmitted to earth by a readout device similar to ordinary television.

Primary Objective

The selection of full-moon lighting indicates that the primary objective was to record the maximum area of the unseen side without particular regard to quality. Side lighting, with accompanying shadows, would have yielded more surface detail at the expense of area coverage. However, full lighting is an understandable choice for anyone trying to explore new territory, especially when the discoverer, as in this case, has the opportunity to name the newly found objects. Future flights will be instrumented to obtain improved quality and to complete the exploration of man's nearest neighbor.

The released pictures have proved to be interesting from several viewpoints. The first impression is that the back side is less exciting and more monotonous than the well-studied front side. This is probably not true. Although there appear to be fewer seas on the back side, there is no reason to assume there are fewer craters, mountains, or other distinctive geological features. More likely, the combination of poor, flat lighting and low resolution has resulted in failure to record such details. After all, until Galileo and the introduction of the telescope, the lunar surface was not well understood, even though it had been studied for many thousands of years.

The lack of gray scale in the pictures is probably due to losses incurred in the many intermediary steps involved in acquiring and assembling the end product. Perhaps more shading will be achieved on future releases. The (CONTINUED ON PAGE 112)

A solid-state UHF radar transponder

Used with the Millstone radar, and employed in Transit and Tiros shots, it combines light-weight and low-power requirements with the ability to provide real-time tracking and orbit determination at very long ranges

By Lincoln Cartledge, MIT LINCOLN LABORATORY, CAMBRIDGE, MASS.
and G. Bradford Tiffany, THE MITRE CORP., CAMBRIDGE, MASS.

Cartledge Tiffany

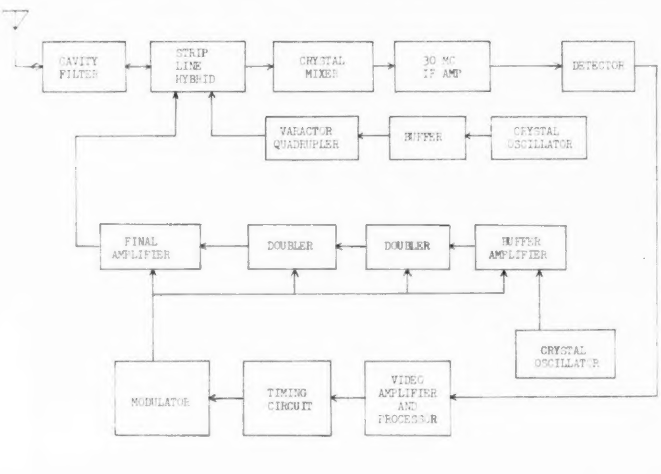
Lincoln Cartledge has been a staff member of the Lincoln Laboratory for four years. After serving as a radio technician in the Navy late in World War II, he attended West Virginia Univ., where he received a B.S. in physics in 1950. His experience before coming to Lincoln Labs was largely as a field engineer with Bendix Radio Div. and Raytheon. At Lincoln, he has participated in a variety of projects related to radar and communications.

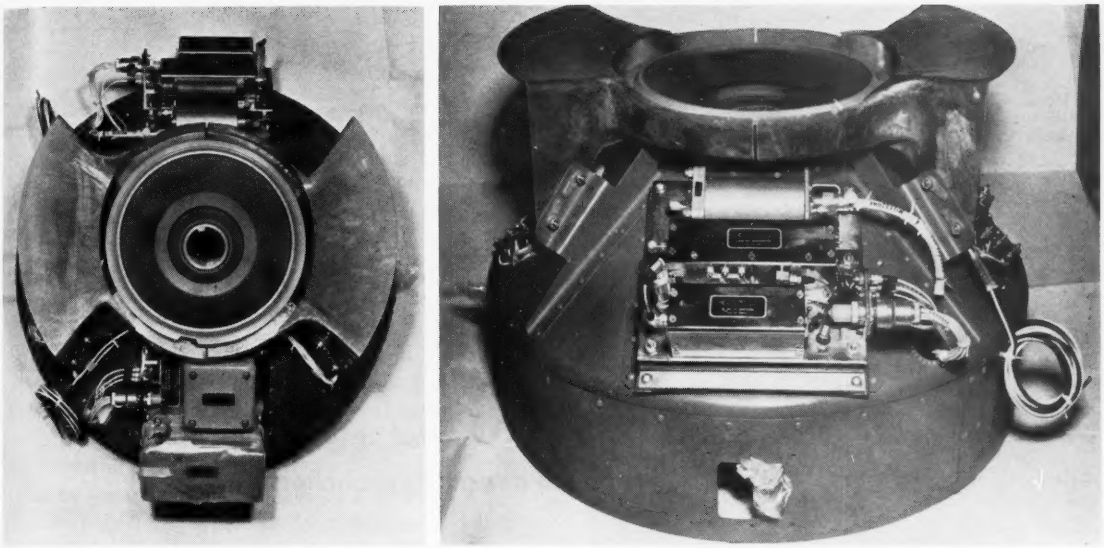
G. Bradford Tiffany was until recently a staff member of the Laboratory, where he was concerned with the development of display and data-transmission systems and high-power radar, and is now on the staff of the Mitre Corp. A 1947 graduate of Emerson College in Boston, Mass., he served immediately afterwards for a time as chief engineer of radio station WERS-FM in Boston, and then was with the Army Signal Corps at Fort Monmouth, N.J., until he joined Lincoln Laboratory in 1952.

IN THE fall of 1957, a long-range UHF radar, located at Millstone Hill in Westford, Mass., was placed in operation by MIT's Lincoln Laboratory. This radar, which has since become well known for its use in interplanetary and moon-bounce experiments, was originally intended for use in investigating new concepts and components for long-range radars, and it was anticipated that knowledge about the radar reflection characteristics of missiles and propagation phenomena could be gained by tracking suitable vehicles. When the radar was developed, targets at the high altitudes and long ranges under consideration were practically nonexistent.

The increased activity at Cape Canaveral in 1958 presented several opportunities to use the Millstone radar for tracking various rockets. Good results could be obtained on the large booster stages, but the second and third stages were too small to be tracked at very long ranges. Even at ranges where the second stage could have been tracked, the radar tended to stay

Block Diagram of Transistorized UHF Transponder





Top and front views of the solid-state UHF radar transponder mounted on the Transit/Tiros payload adapter.

"locked" onto the larger first stage, so that acquisition of the second stage when it separated from the booster was very difficult.

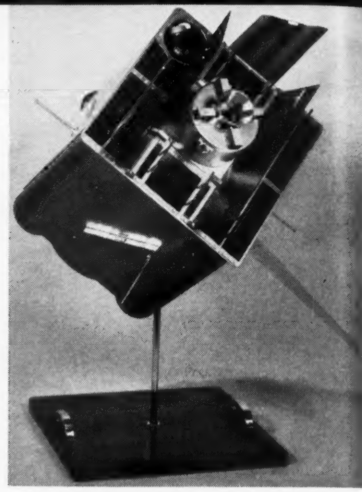
About May 1958, Space Technology Laboratories (STL) requested tracking assistance on some nose-cone re-entry tests. A meeting was held at Lincoln Laboratory to discuss the radar aspects of this problem. It became painfully obvious that, although Millstone was the most powerful radar available at that time, it was not powerful enough to track targets as small at ranges as great as STL was contemplating. The meeting resulted in a recommendation that the vehicle to be tracked carry an active radar-tracking aid.

The transponder system with the Navy's experimental Transit satellite, which was expected to make a second try for orbit in April.

Tracking Aids Are Old Stuff

Active tracking aids are about as old as the radar art itself. One volume of the MIT Radiation Laboratory series is devoted to the subject. In fact, most, if not all, present missiles and satellites carry active tracking aids of one kind or another. These range from heavy microwave transponders to light and simple CW transmitters, which may double as telemetry transmitters. The former are often part of extremely accurate initial guidance or tracking systems. Because of this extreme accuracy, as well as limitations in the cooperating ground equipment, conventional beacons are usually too costly in weight and power to be carried on second or third stages. While the simple CW transmitters are small and light enough to be carried in the smaller satellites and powered by solar cells, their usefulness as real-time tracking aids is limited.

What was needed was a system midway between these two extremes. The Millstone Hill Radar had enough power and sensitivity to permit the use of a transponder with moderate capability, and the use of such a transponder with the Millstone system would provide real-time tracking of small targets at very long ranges. (CONTINUED ON PAGE 114)

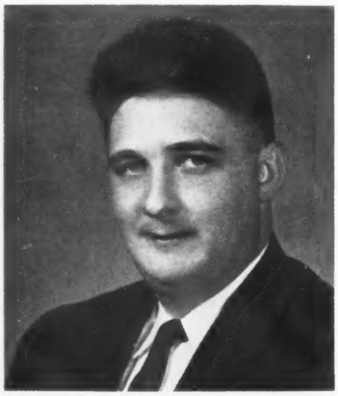


A recoverable interplanetary space probe

The features of this automatic probe give a preview of second-generation electronic and electromechanical design approaches

By Milton B. Trageser

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.



Milton B. Trageser is a group leader in the Instrumentation Laboratory and a lecturer in the Department of Aeronautics and Astronautics of the Massachusetts Institute of Technology. After receiving a B.S. in physics from MIT in 1951, he began his nine years of experience in the field of self-contained guidance and control systems at the Instrumentation Lab. He first worked on ball-bearing losses, thermal problems, and various mechanics problems related to the development of high-performance gyroscopes. Then he worked on inertial-guidance system synthesis, development, and testing on Spire and Spire Jr. navigation and bombing systems and in the Laboratory's inertial-guidance programs for the Atlas, Thor, and Titan weapon systems. His primary effort during the past two years has been on interplanetary navigation and the preliminary design of a recoverable interplanetary space probe.

THIS ARTICLE describes some of the highlights of a preliminary design for a space mission that has held the interest of a group of people at Massachusetts Institute of Technology for the last two years. As a matter of fact, the subject presented sufficient interest so that we experienced little difficulty in obtaining the enthusiastic collaboration of several other organizations in preparing a preliminary design—specifically, Avco Corp. on re-entry, MIT's Lincoln Laboratory on communications, and Thiokol's Reaction Motors Div. on a small rocket for making navigational corrections. So, we are about to relate ideas and work of numerous individuals and several organizations.

We envisioned a photographic reconnaissance of Mars or Venus by a refined probe which would guide itself close to the planet, train a camera on it and take one picture, and then, having passed the planet in a carefully planned manner, make a return trip to earth, where it would re-enter and be recovered.

In planning this probe, we went into enough detail to appreciate all of the engineering problems associated with it as a representative of a second-generation space device; and we developed numerous ideas and techniques related to interplanetary space-probe operation, reliability, guidance and control, telemetry, and other problems that apply equally well to a variety of interplanetary ventures, including planetary impacts, satellites, and near passes. Moreover, we decided to study the smallest, lightest, simplest, and, hopefully, most reliable device which could circumnavigate the solar system and make a very creditable planetary reconnaissance.

Let us look at such a probe first in terms of orbits. There are many types of round-trip, free-fall orbits to Mars or Venus, requiring different launch dates and velocities, trip times, and so forth. The illustrations on the opposite page show a typical low-energy, slow round trip to Mars. On June 17, 1962, a rocket boosts the probe to a velocity of 38,200 fps in a specified direction, and it proceeds

on a trajectory with apogee beyond the orbit of Mars. During the next 2.4 years, the vehicle goes around the sun more than one and one-half revolutions. Several navigational velocity corrections are made during this interval. On Nov. 17, 1964, the vehicle passes Mars at an altitude of 4690 miles and with a velocity of 11,390 fps relative to Mars at the closest approach. During the close passage, the gravitational field of Mars, of course, acts strongly on the vehicle. The large difference between the outbound and the inbound paths is a consequence of this effect. The return takes 0.8 years. This makes the round-trip time 3.2 years. In the return trip, the probe travels more than one-half revolution around the sun and re-enters the earth's atmosphere with a velocity of 43,000 fps on Sept. 6, 1965. Several of these trajectories were studied, including ones to Venus and ones of shorter trip time.

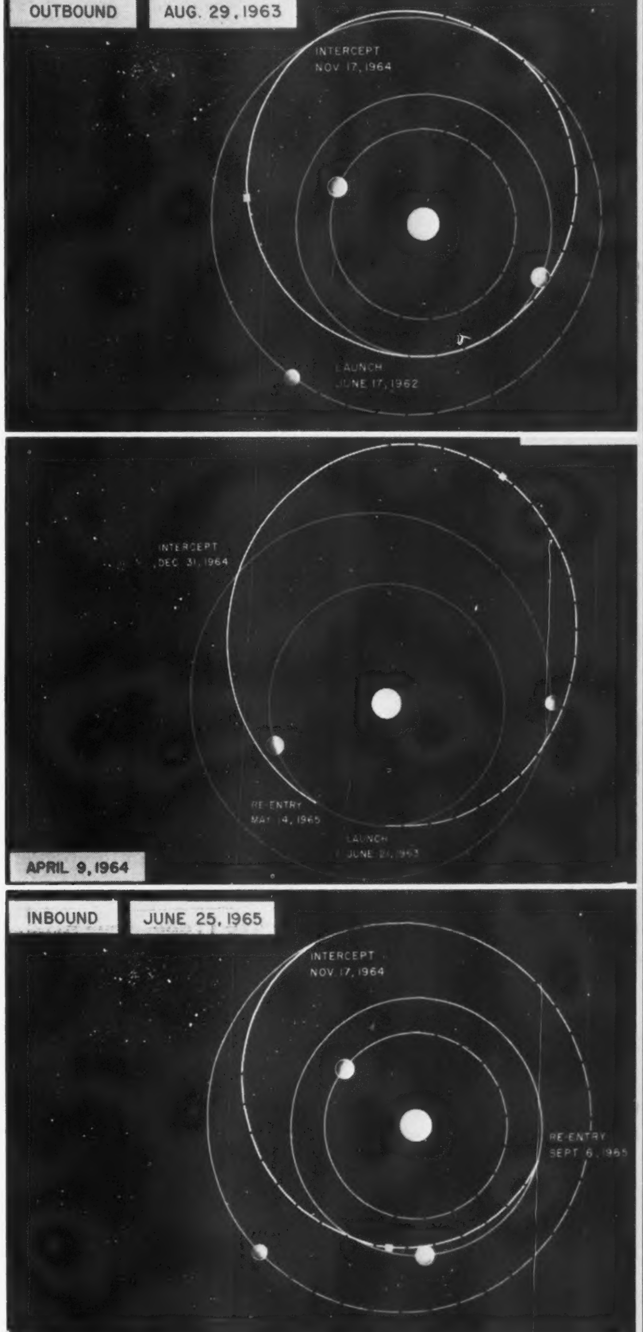
Interplanetary missions have stringent navigational requirements. This is especially true of round-trip orbits, since a 100-mile error in planet-passing distance for the orbit just described causes a 60-fps velocity error after Mars has been passed. This error would cause an error of the order of magnitude of 100,000 miles in the return to earth if it were not corrected.

We sought to solve this problem with a completely self-contained guidance system. The system has an optical instrument able to measure angles between pairs of celestial bodies—the sun, the planets, and the six brightest stars. To obtain a position fix, five or six geometrically strong angles between pairs of these bodies, as shown in the figure on page 116, are measured with an instrument having 10 in. arc rms error. To calculate the necessary velocity correction, this fix data and data from the previous fix are combined with stored data in a probeborne digital computer. Correction is then made with an accuracy of 1 percent in magnitude and direction.

Typical Velocity Corrections

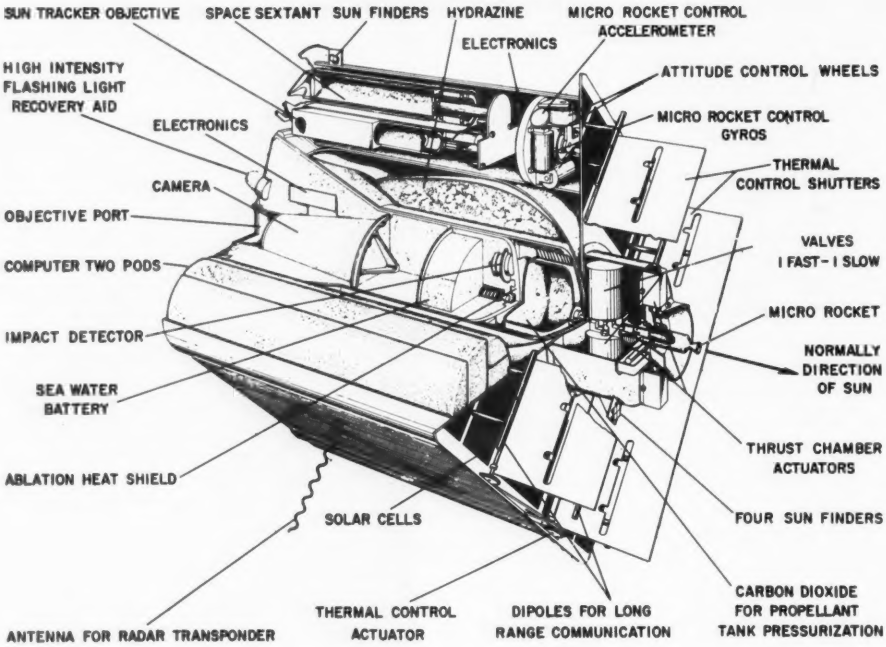
The table on page 118 gives a typical program of velocity corrections in the Mars round trip just described, based on these assumed errors (rms values): 0.1 percent booster guidance error; 10 sec of arc-angle measurement errors; 1 part in 10^5 error in keeping time; and 1 percent error in applying velocity corrections. These values demand only a reasonable amount of propellant for navigational corrections.

Two features in the tabulated data may surprise the reader. First, that the knowledge of time does not steadily get worse but actually reaches a maximum error and then improves. This is a result of using a modest clock with errors of one part in 10^5 and of correcting it with the redundant fix data.



3.2-Year Mars Trajectory

Normally Sunny Face



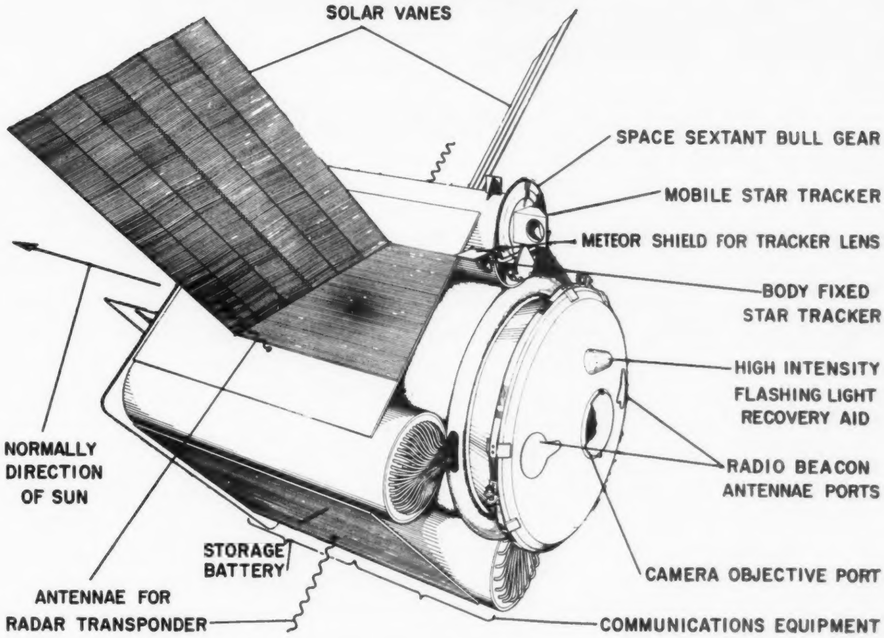
The time can actually be deduced from the celestial observations with a better accuracy than that resulting from the 0.1 hr per year clock error. The second feature of note is the smallness of the error in knowledge of the position at the destination based on a fix made one or several days earlier and having 20 times this error. This results from the inaccuracy in the fix being primarily in range from the planet.

Principal Features of Space Probe

Now let us look at the probe itself. The diagrams and tables on pages 34-35 describe its chief features. Subsystems include a general-purpose digital computer, electromechanical-optical equipment for navigation and attitude control, a microrocket for applying velocity corrections, a long-range communications transmitter for telemetry, a radar transponder for impact prediction, and a re-entry vehicle containing the camera and recovery aids.

The attitude-control system normally holds the vehicle with its energy-collecting face toward the sun by using four small prism sensors with flywheels in a nonlinear closed loop. Reaction torques from accelerating these flywheels rotate the probe to hold these sensors toward the sun. The solar vanes are important components of the attitude-control system. By occasionally using solar-radiation pressure to apply torques on the vehicle, the average flywheel speeds are maintained close to zero. The low-average flywheel speeds result in very low long-term power requirements and much reduce the required life of wheel bearings. Further, this occasional torquing prevents the flywheels from becoming saturated by other smaller torques acting on the probe for long periods of time.

The second application of the attitude-control wheels is the training of the telescopes of the space sextant on their assigned targets. The sun tracker in this instrument is body-fixed in the probe. By operating the flywheels with the signals from the sun tracker, the sun tracker can be precisely aimed at the center of the sun. With the approximately known angle between the sun and a specified bright star or planet set into the precision drive between the sun tracker and the mobile tracker, a search is made about the sun by rotating the whole probe while tracking the sun with flywheels. When the second object is found in the field of the mobile tracker, the precision sextant drive is adjusted to measure accurately the angle between the sun and the star or planet. A body-fixed star tracker is also part of the space sextant. To measure the angle between a star and a planet, the probe is rotated using the attitude-control system together with the space-sextant drive so that this body-fixed tracker points at the previously located navigational star. Then the planet is found and the angle from the star to the planet is measured in the same manner that the



star was found and was measured.

The operation of all equipment is controlled by the general-purpose digital computer. Some unusual techniques permit the reliable and efficient storage of a large program and allow the operation of this computer at various speeds with low-power requirements. In the standby mode of six operations per second, the computer requires only 10 mw. It controls all the accessories through three types of input-out devices, relays, transistor memory elements, and a forward-backward counter.

Microrocket Makes Correction

Having made a navigational fix and reduced the data to obtain the necessary velocity correction, the vehicle makes this correction with its microrocket (1-lb-thrust) subsystem. The vehicle starts this operation by tracking the sun and a known navigational star. Then, by counting flywheel revolutions, the vehicle is positioned so that the axis of its rocket is along the direction of the desired velocity change. The rocket is then fired. Solenoid actuators on the nozzle and two small control gyros in the electromechanical pod operate in nonlinear closed loop to maintain the vehicle on this desired heading. A small, unbalanced, watch-movement accelerometer in the electromechanical pod measures the resulting velocity change and provides the cutoff signal for the rocket when the desired change has been completed. The 100 lb of hydrazine are sufficient for velocity corrections totaling more than 2200 fps, and this is more than adequate for round-trip flights to Mars or Venus.

After the correction is made, the energy-collecting face is turned toward the sun. On this face is a battery of solar cells (CONTINUED ON PAGE 116)

Weight Analysis (lb) of Recoverable Probe

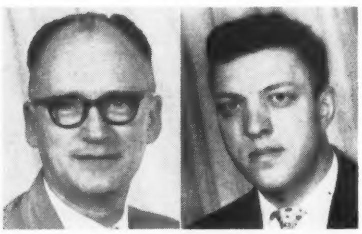
Structure and propellant tank	65
Computer (two pods)	30
Mechanical control components	
Space sextant	13
Attitude-control mechanical components	7
Electrical components	
Control electronics	20
Communications	6
Batteries	24
Microrocket subassembly	
Monopropellant (hydrazine)	100
CO_2 pressurization	6
Thrust-chamber assembly	10
Re-entry Vehicle	
Camera	10
Instrumentation, recovery aids	11
Structure and head shield	26
Miscellaneous	10
Total	**338**

Television cameras for space exploration

The marvelous eye of television begins to take a major role in satellite and space-probe reconnaissance, moon exploration, biological monitoring, and other space technologies

By M. H. Mesner and J. R. Staniszewski

RCA ASTRO-ELECTRONIC PRODUCTS DIV., PRINCETON, N.J.



Mesner Staniszewski

Max H. Mesner received a B.S.E.E. degree from the Univ. of Missouri in 1940. That same year he joined the RCA Manufacturing Co. in Camden as a radio engineer assigned to airborne radar equipment. In 1942, he went with the RCA Laboratories in Princeton, N. J., and there did research and development work on television cameras, studio equipment, and color TV receivers as well as storage and computer devices. Joining Astro-Electronic Products Div. upon its formation, he has been engaged in the development and design of TV cameras for satellite use, and is currently the project engineer in charge of TV camera design for a satellite.

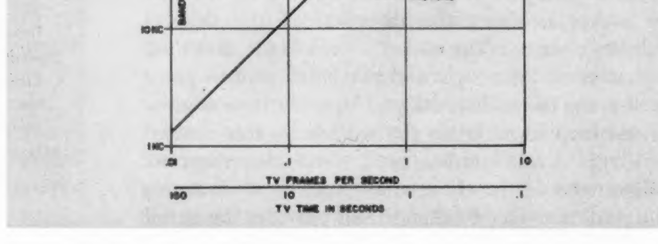
J. R. Staniszewski received a B.S. degree in physics from the Carnegie Institute of Technology in 1950 and is currently doing graduate work at the Univ. of Pennsylvania. From 1950 to 1953 he worked as a field engineer attached to the Military Assistance Advisory Group in the Netherlands, and then joined RCA's Defense Electronics Products Div., working on design and development of automatic tracking circuits for Mod. II Shoran and closed-loop TV utilizing a sensitive image-orthicon. Recently his work has been on a miniature TV camera for use in space vehicles.

Explorations of outer space will be done with the use of television, which will extend man's vision to these new frontiers without exposing his person to its dangers. Such cameras have been designed and tested to survive the space environment, and are ready to be used for space exploration.

Examples of remote outer-space photography have already reached the public. Photographs of the earth and its cloud cover were made as early as 1954 from a V-2 rocket, and more recently from an Atlas, by including cameras aboard the rocket and recovering the film for processing. The unusual information garnered from these photographs confirms the desirability of incorporating television cameras in orbiting vehicles. For instance, a periodic coverage of the earth would supply valuable aids to the meteorologist, enabling him to make more accurate long-range weather forecasts.

These experiments also emphasize the desirability of using

Bandwidth vs. Frame Time



television in space vehicles for viewing distant planets from a closer position. In this area, designs, such as the Naval Ordnance Test Station (NOTS) and Space Technology Laboratories (STL) sensors for producing television-like images, were arranged for the Pioneer I and Pioneer III payloads. These sensors were designed to utilize the vehicle motions to accomplish both line and frame scanning with a single photosensitive element providing a video output. By expanding periods for scanning and transmitting a single low-resolution picture to two hours, bandwidth was reduced sufficiently to be accommodated by the microlock telemetry system. The effectiveness of these sensors was not established, however, because of system failures.

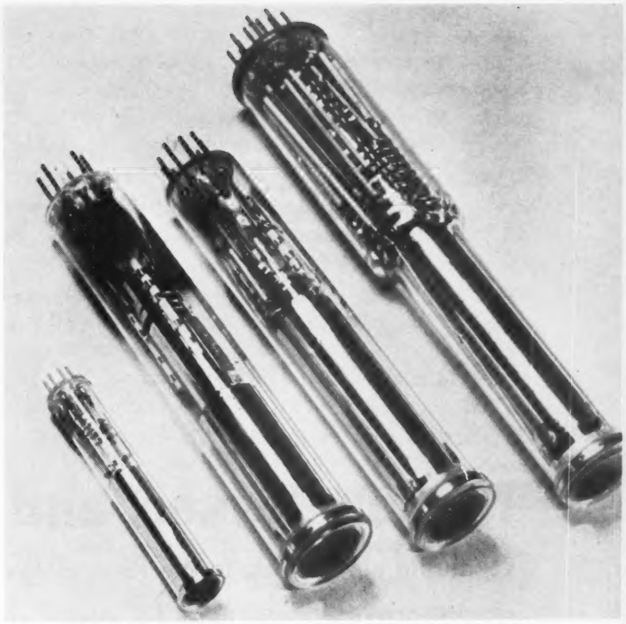
Miniature TV Camera Offers Advantages

A miniature television camera extends these explorations a step further by offering high-resolution scene information at a cost of almost no additional instrument weight and a modest increase in transmitter power. In addition to the attractive features of a re-useable photosensitive surface, it also possesses a high immunity to radiation effects and does not burden the designer with the recovery problems which have made film processes so mechanically complex in space projects.

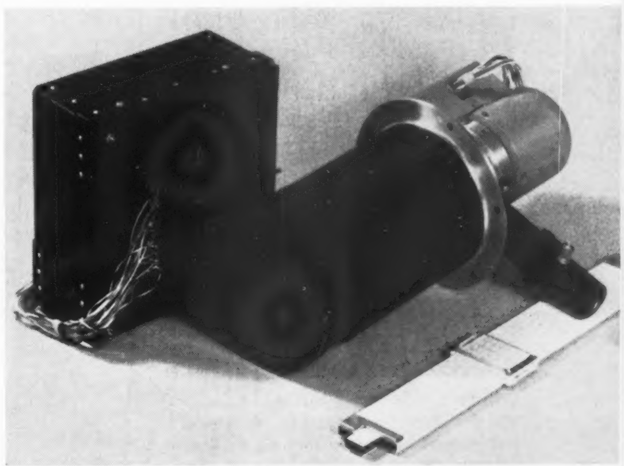
There are a number of applications for the television camera which are of immediate interest. As previously noted, one of the most important of these is viewing the earth and its cloud cover from an orbiting vehicle to provide mapping information for weather forecasting. This is the purpose of the Tiros program, which will be described in a forthcoming issue of *Astronautics*.

Also, before man is sent into space, animals will be used to study the physiological effects of the space environment. A television camera can provide an excellent means for observing the reactions and health conditions of these animals. In a similar manner, television observations of man in space will provide the field of space medicine with an estimation of the physical condition of the Astronaut.

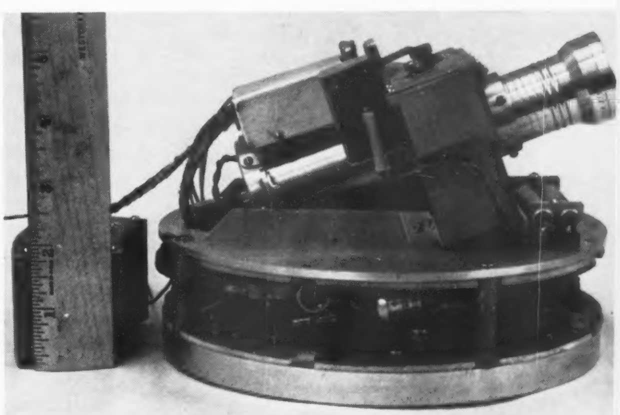
The Stratoscope I balloon experiment, in which a television camera was used to point a large-aperture telescope for observing celestial bodies from outside the earth's atmosphere, illustrates another potential use for television in space. In addition, television techniques can be used for a direct view of the Moon, Mars, Venus, and other planets from optimum vantage points in space and send back close, detailed views of these celestial bodies. Without too much imagination, we can envision camera-bearing vehicles which would map Mars from an orbit or view the surface of Venus for the first time by orbiting (CONTINUED ON PAGE 126)



A half-inch vidicon compared to three 1-in. vidicons.

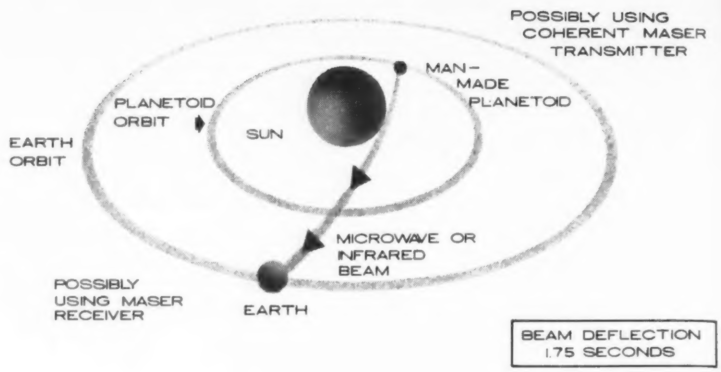


The complete wide-angle camera for Tiros I.



Space exploration camera for a lunar probe.

As indicated in this illustration, masers may make possible a means of measuring curvature of space, and thus provide a verification of the General Theory of Relativity.



Maser, Iraser, and Laser

Quantum electronics, in the form of low-noise amplifiers and atomic clocks, provide new tools for space and relativity experimentation

By Harold Lyons

HUGHES RESEARCH LABORATORIES, MALIBU, CALIF.

Harold Lyons, head of the Atomic Physics Dept. of Hughes Research Laboratories, invented the world's first "atomic clock" in 1949 while at the National Bureau of Standards, where he was a physicist and chief of the microwave standards section from 1941 to 1955. His background includes a B.A. in physics, magna cum laude, from the Univ. of Buffalo in 1933, a Ph.D. in physics from the Univ. of Michigan in 1939, postdoctoral research at the Univ. of Michigan, and research at NRL before joining NBS. The recipient of numerous awards for his research and inventions, Dr. Lyons was honored last year for his invention of the atomic clock by the Franklin Institute, which cited "his work in pioneering the development of clocks of very great precision based on the natural periods of vibration of atoms and employing microwave techniques." Dr. Lyons joined Hughes in 1955 and now, among many duties, directs its atomic clock project under a development contract from NASA.

In recent years, the science and techniques of electronics have gone beyond the traditional use of free electrons and broached the investigation and use of electrons which are bound or captured. Instead of using electrons in thermionic emission, we put them to work while they are still bound to an atom or molecule or are confined with trillions of their fellows in the intricate latticework of a crystalline solid. Indeed, we even impress nuclei or whole atoms and molecules into the service of electronics.

This revolution is often referred to as solid-state or molecular electronics. A better name might be quantum electronics, since it is often the quantum-mechanical properties which are of interest. Bound electrons exhibit exciting new properties as compared to free electrons. Typical quantum behavior is observed, as electrons can exist only in discrete energy levels or states in which they can store radiant energy. Transitions between suitable energy states are accompanied by the emission or absorption of energy at frequencies from radio to optical ranges analogous to the oscillations of a classical resonator. Atomic elements can be used which provide all circuit functions of resistance, inductance, and capacitance encountered in ordinary electronics.

Atomic circuit elements are particularly useful because they are all exactly alike, manufactured for us by nature. This favors their use when attempting work in the millimeter or higher bands—a spectral region as yet unconquered by conventional devices. By incoherent methods of excitation, atomic systems can be made to store energy in stationary states and then deliver this energy as coherent radiation.

This is a unique and most important property, one particularly

useful in attempting to produce continuous-wave radiation in the infrared or optical regions. Atomic systems are very low in noise, since they can be cooled to low temperatures and have no shot noise. Amplifiers made with quantum systems which store energy can therefore have unprecedented sensitivity. The stored energy is released by the process of stimulated emission when the signal to be amplified illuminates the atomic sample. This method of amplification was first developed by Gordon, Zeiger, and Townes, who called a device based on this principle a Maser, an acronym for "Microwave Amplification by Stimulated Emission of Radiation." Similarly, we derive the words Iraser and Laser for the equivalent *infrared* and *light* (optical) devices.

Two Distinct Classes of Masers

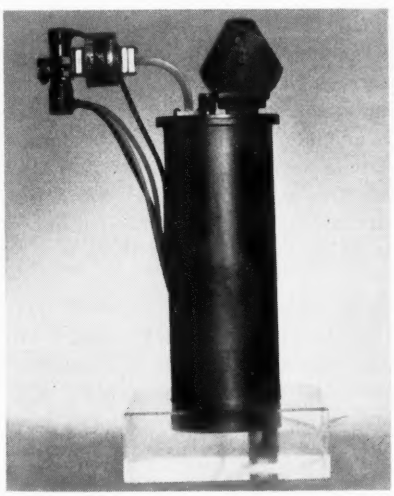
Masers are divided into two distinct classes—those using atomic or molecular beams and those using solids. The beam types are most suitable as stable oscillators; the solid types make good amplifiers. The beam masers are also simpler, and so will be described first.

According to quantum mechanics, an atomic system like a molecule can exist in any of a series of discrete energy levels, or states. The molecule can make transitions between these levels, absorbing energy in going to a higher level and emitting it when going to a lower. One way to cause transitions is by an interaction with radiation; that is, an electromagnetic wave can excite the molecule by losing energy to it in absorption or gaining energy from it in emission. In making a transition between two levels, the energy change $\Delta E = h\nu$, where h is Planck's constant and ν is the frequency of the radiation absorbed or emitted. The transition can be thought of as equivalent to the resonance of a classical oscillator, the molecule being stimulated when the wave frequency is equal to its natural resonant frequency.

The occurrence of absorption from the wave, or emission to it, depends on whether the molecule is in the lower or upper state of the transition involved. The probability of transition is exactly the same in both cases, so that normally a net absorption occurs, because more molecules are in lower than in higher energy levels.

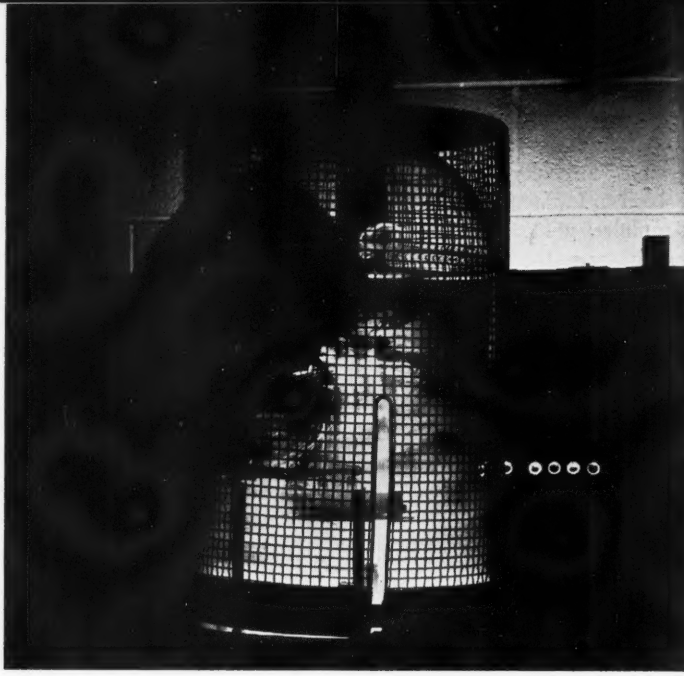
In the ammonia maser, a net emission of power from the beam is desired. As this is impossible for a gas in thermal equilibrium, it is first necessary to get rid of the lower-state molecules. The focuser accomplishes this task. It consists of a set of charged wires or electrodes which set up an intense, nonuniform electric field which deflects the "good" and "bad" molecules in opposite directions. A maser gives almost 100 percent separation.

After the emitting molecules in the maser beam enter the cavity, the thermal radiation in the cavity initiates emitting transitions by the process of stimulated emission. The molecules in the beam are forced to emit radiation in phase with the cavity wave. The resulting radiation is therefore extremely monochromatic or coherent, all the power being generated in a very narrow frequency range with fractional width of about 10^{-13}—or one part in 10 million million. This is the most coherent radiation ever produced, and is an indication of the noise-free character of maser action because of the lack of shot noise. Originally, the molecules obtained their energy by incoherent processes such as collisions, coming into thermal equilibrium by interaction with their environ- (CONTINUED ON PAGE 100)



Left, a small, X-band ruby maser developed at Hughes Research Laboratories. Cooled with liquid nitrogen to 77.4 K, this maser has 15 mc gain-bandwidth product, which can perhaps be increased to 50 mc by use of a double cavity. Right, the maser apparatus removed from its case, showing ruby-filled cavity at the bottom of the waveguide and the small size of magnet required.

ARF physicist William Brennan, observing the preparation of substrate to receive a thin selenium film, takes on the materials-research scientist's aura of modern Merlin.



Space Age electronic materials

Search for materials to meet the demands of spaceflight moves into unexplored areas of solid-state physics and to the threshold of a new era in electronic design

By John W. Buttrey

ARMOUR RESEARCH FOUNDATION, CHICAGO, ILL.

John W. Buttrey is supervisor of research in solid-state physics at Armour Research, which he joined as an associate physicist in 1953, upon completion of his Ph.D. work at the Univ. of Missouri. Dr. Buttrey assumed his present position in 1956, and has since conducted and supervised programs in semiconductors, small-angle X-ray diffraction, thin films, and other solid-state fields. His colleagues W. D. Brennan, E. A. Fagen, and R. J. Robinson of the ARF solid-state physics group contributed to the discussion.

JUST AS Sputnik I ushered in the Space Age in 1957, the invention of the transistor in 1948 opened a new era in electronics. The transistor performed many electronic functions which at that time were possible only with vacuum tubes which had large power requirements for cathode heating and the attendant problem of heat dissipation; and it performed these functions as well as or better with negligible power and small size.

Perhaps the most important function served by the invention of the transistor was to father a research effort that explained transistor action in the elemental semiconductor, germanium. This research has led to the use of germanium, and later silicon and other materials, in a myriad of solid-state electronic devices which allow partial or complete replacement of the electron tube in many electronic circuits. More important, the understanding of the mechanisms in semiconductors led to a group of devices for which there was no vacuum-tube analog.

Now, with the advent of high-speed flight and space travel, there is an ever-increasing demand for small devices and compact circuits which will operate reliably over a wide range of conditions. The stringent restrictions on space and weight in the airborne electronics which guide, detect, aim, and power modern vehicles have made the search for small and light weight electronics critical. Present materials, such as germanium and silicon, are proving in-

adequate for the job at hand. As a consequence, the search for materials which will do special jobs is relentless and somewhat awesome in magnitude.

While semiconductor devices are not the only ones which will play an important role in the circuit functions of the future, they will probably perform a lion's share of the work. Let us digress, then, for a moment to look at the elementary mechanisms of semiconductor behavior. For a more complete picture, there are several recent books on the subject, which are listed at the end of this discussion.

What Comprises Ideal Semiconductor

A pure, ideal semiconductor can be pictured at absolute zero as being a material whose valence levels are completely filled but whose outer levels are completely empty. The valence levels are a continuum of levels and this continuum is called the valence band. The continuum of outer levels is known as the conduction band. The diagram on page 124 shows this structure. The two bands are separated by a region in which electrons find no allowed energy levels. Such a semiconductor is best exemplified by pure germanium or silicon. These materials, from the Group IV elements, have interatomic bonding such that the four valence electrons of each atom are used in the binding arrangement. Such electrons can become available for conduction upon the absorption of a certain amount of energy E_g, indicated on the diagram.

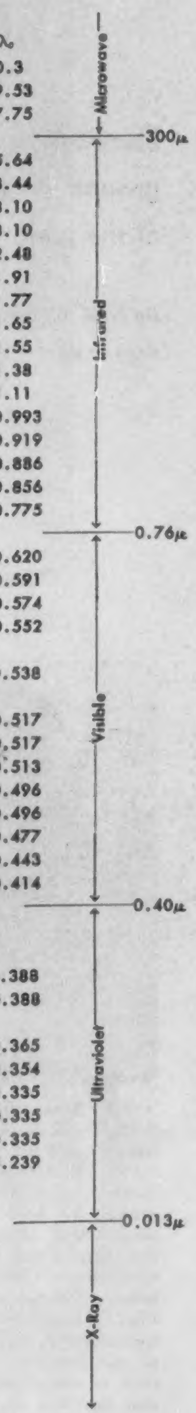
In these semiconductors, certain Group V impurities exhibit a loosely held "fifth" electron in the crystal lattice. This fifth electron becomes available for conduction upon the absorption of a small amount of energy, corresponding on the diagram, page 124, to E_D. Such levels are known as "donors," since they donate an electron to the conductivity. The levels are discrete in space; that is, the impurities are separated by many atomic distances, and there is no net transport of electrons in these levels when an electric field is applied.

In addition to conduction by electrons, there is one other kind of conduction mechanism in semiconductors. In intrinsic (pure) germanium, for example, when an electron has been excited into the conduction band, and moves through the crystal, it leaves behind a deficiency of one electron, or a net positive charge of one electron unit. This is known as a "hole." A hole has the ability to move through the crystal, in a manner analogous to a positive electron.

When an electron is excited from a donor level into the conduction band, it leaves behind a hole, but this hole is trapped by the discreteness of the donor levels. There is also (CONTINUED ON PAGE 121)

Semiconductor band gaps and wavelength cut-offs. Wavelengths calculated from $2_c = 1.24/E$ where λ_c is in microns and E is in electron volts.

Semiconductor	E	λ_c
α = Sn	0.06	20.3
Bi_2Te_3	0.13	9.53
InSb	0.16	7.75
PbTe	0.22	5.64
Te	0.36	3.44
InAs	0.40	3.10
PbS	0.40	3.10
PbSe	0.50	2.48
GaSb	0.65	1.91
GaSn	0.70	1.77
Ge	0.75	1.65
Mg_3Sb_2	0.80	1.55
B	0.90	1.38
Si	1.12	1.11
InP	1.25	0.993
GaAs	1.35	0.919
Cu_2O	1.40	0.886
CdTe	1.45	0.856
AlSb	1.60	0.775
Se	2.00	0.620
ZnTe	2.10	0.591
AlAs	2.16	0.574
GaP	2.25	0.552
$C_{24}H_{12}$ (Coronene)	2.30	0.538
Pthalocyanine	2.40	0.517
In_2Te_3	2.40	0.517
CdS	2.42	0.513
S	2.50	0.496
Se	2.50	0.496
ZnSe	2.60	0.477
AgI	2.80	0.443
AlP	3.00	0.414
5,6 N pyridino -1,9 benzanthrone	3.20	0.388
ZnO	3.20	0.388
Hydroviolanthrone	3.40	0.365
SiC	3.50	0.354
ZnS	3.70	0.335
TiO_2	3.70	0.335
Napthalene	3.70	0.335
Diamond	5.20	0.239
Boron Phosphide	5.90	



X-15 operations: Electronics and the pilot

Electronic equipment figures prominently in X-15 flight and ground systems, but this hypersonic vehicle is an instrument of the pilot, depending on him for control and flight success

By Neil A. Armstrong

NASA FLIGHT RESEARCH CENTER, EDWARDS AFB, CALIF.

Neil A. Armstrong, a member of the X-15 pilot team, is an aeronautical research pilot and engineer at the NASA Flight Research Center at Edwards AFB, Calif. A former Naval aviator, he holds a B.S. degree in aeronautical engineering from Purdue Univ., and has done graduate work at the Univ. of Southern California. For the past five years at the Flight Research Center, he has specialized in the operating problems of high-performance research aircraft, such as use of a pilot in the launch and injection of multistaged orbital vehicles and techniques necessary for the landing of very low lift to drag ratio aircraft.

The long-awaited first glide flight of the X-15 was successfully completed last June and was followed by the first powered flight last September. The first X-15 aircraft is now being operated by the NASA Flight Research Center at Edwards AFB, Calif. Two additional aircraft are being operated by North American Aviation pending completion of the contractor demonstration. The value of this type of research tool rests in its ability to expose itself to moderately high-performance flight regimes repeatedly and reliably.

The X-15 electronic systems were planned to assure maximum utility and safety with the aircraft and to permit a maximum amount of research information to be recorded and presented in its most useful form. A review of the functions of the X-15 electronic systems and their relation to the success of flights may prove valuable in the design and specification of future manned systems.

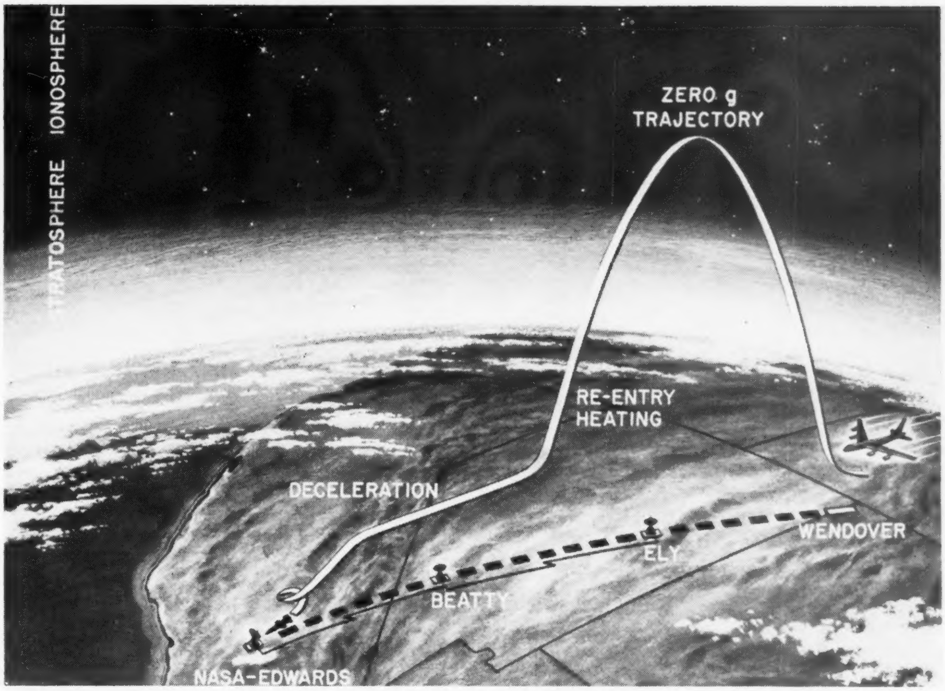
The X-15 is, in concept, a self-contained data gatherer. Once dropped from its B-52 carrier, it is capable of rocket boost to a high-velocity, high-altitude zero-g trajectory of long duration, of re-entry at a wide range of flight conditions, and of performing a poweroff approach and landing at the home station—Rogers Dry Lake at Edwards AFB.

Although inner-loop damping augmentation is provided about all three aircraft axes, the vehicle is controlled exclusively by the pilot in the conventional fashion. The research measurements are recorded on board the aircraft on oscillographs. Parameters of interest include those required for the analysis of aerodynamic and structural heating, control at low dynamic pressure, and exit and re-entry.

It was deemed advisable to fly the X-15 over an instrumented ground range in the interest of flight safety, maximizing data acquisition and providing convenience in the general operation. The subsequent integration of this range (High Range) with the airborne procedures makes it appropriate to include a brief description of the ground range before discussing flight functions as such.

High Range is basically a radar space-positioning and communications net over the proposed trajectory of the research aircraft, as illustrated on page 43. In addition, it includes equipment for telemetry monitoring, telemetry recording, and master timing for data correlation. As can be seen in the illustration, the range is a series of three

X-15 Trajectory Over High Range



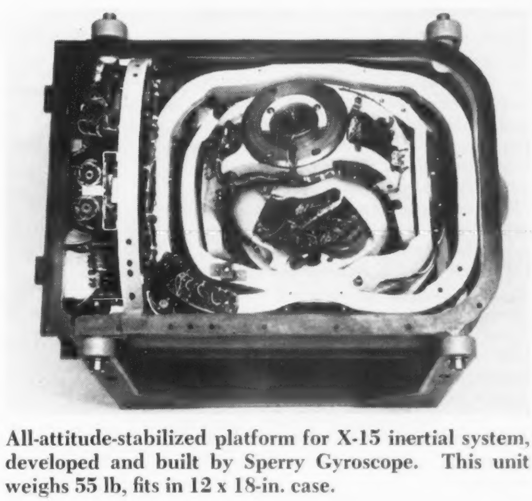
stations, including the master control at the NASA Flight Research Center. The range was located to minimize interference with civil airways and provide suitable intermediate launching areas to permit a logical buildup of the flight program to the maximum performance flights. The radar equipment, constructed by the Reeves Instrument Corp., is a modification of the AFMTC Model II similar to that used on the Atlantic Missile Range. These automatic angle and range-tracking units operate on S-band and have 400-mile ranging-circuit capability. The units are located to provide adequate overlap capability and omnidirectional tracking down to an altitude of 10,000 ft.

Electronics in Actual Flight

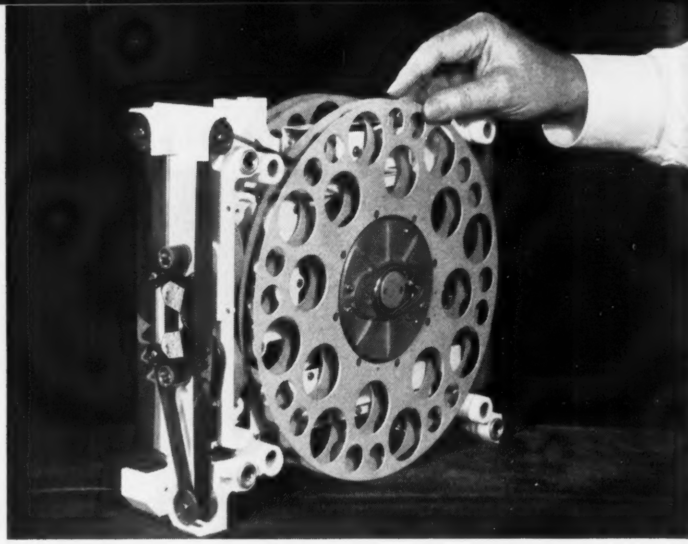
As to actual flight, some areas which incorporate electronics in a primary or secondary manner are flight-condition information, aircraft system-performance information, communications, and navigation.

Quantities of interest to the pilot, whether or not the aircraft is within or outside the sensible atmosphere, include trajectory velocity, vertical velocity, altitude, precision pitch attitude (for re-entry), and attitude about all three axes.

In addition, along-range and cross-range velocities are required for research data. Conventional pressure sensors and simple gyroscopes are not used because they do not function adequately throughout the X-15 mission. Doppler and radio techniques were eliminated because of their attitude limitations and power and cooling requirements. The inertial-platform concept proved (CONTINUED ON PAGE 76)



All-attitude-stabilized platform for X-15 inertial system, developed and built by Sperry Gyroscope. This unit weighs 55 lb, fits in 12 x 18-in. case.



The Mercury capsule's tape recorder (case removed), designed for operation in a pure oxygen atmosphere.

Project Mercury tape recorder

The unusual requirement of operation in a pure oxygen atmosphere paced development of this unique recorder

By G. W. Boyer

CONSOLIDATED ELECTRODYNAMICS CORP., PASADENA, CALIF.

G. W. "Wes" Boyer is chief design engineer of CEC's Datalab Div., responsible for design of tape recorders. His broad experience in this field began with tool design more than 20 years ago. His first contact with magnetic tape products came in 1946 with the government agency responsible for design and development of complicated cryptographic equipment, where his work led to a device used by all the services to send and receive secret messages by scrambling and reconstructing voice transmissions. From 1950 to 1956, when he joined CEC, he was with Vitro Corp., in charge of a design group serving as consultants to the Bureau of Ordnance on missile-launching systems, weapons, and countermeasures. He holds three patents in his own name and has five pending.

THE SAFETY of the Astronaut in a confined environment over which he has limited control and successful completion of the programmed mission—these primary objectives of NASA's Project Mercury imbue each individual design requirement in the program with exceptional significance. When, for instance, the Datalab Div. of Consolidated Electrodynamics Corp. received the contract to design, develop, and manufacture the tape recording system for the Mercury capsule last spring, we found these requirements would take us beyond the commonly thought of specifications for recorders.

Advances in the state of the art, we believed, would assure a design with excellent temperature, pressure, acceleration, and shock performance; and we had confidence that we could make the necessary strides in component miniaturization and production techniques to develop a small and reliable system.

The stickler in the tape recorder development was the unusual requirement of operation in the 100-percent-oxygen atmosphere of the Mercury capsule. McDonnell Aircraft Corp., NASA's prime contractor for the Mercury capsule, specified that all materials had to operate continuously for 24 hr in 100 percent oxygen at a pressure of 5 psia without (1) producing irritating or objectionable odors, toxic gases, oxidation, or other chemical deterioration of the oxygen or (2) causing a spontaneous fire or explosion.

Selection of materials was complicated by the fact that the recorder will encounter high temperatures during launching and reentry. The material chosen could not pollute the oxygen under high-temperature conditions (temperature range specified was —15 to 200 F), and had to retain structural strength or shape, even under 10-g vibration from 5 to 2000 cps, continuous acceleration to 6 g along all axes, and shock to high g.

Most metals could operate under the (CONTINUED ON PAGE 52)

Four of the participants in the NASA conference on lunar research answer questions from the press on the scientific importance of the moon. From left, Thomas Gold of Cornell Univ., Robert Jastrow of NASA, Harold C. Urey of the Univ. of California, and Harrison Brown of the California Institute of Technology.

NASA lunar research conference

Approaching lunar explorations stimulate new thought and lively scientific debate over mysteries of the moon

By Robert Jastrow, Gordon J. E. MacDonald, and John A. O'Keefe

NASA GODDARD SPACE FLIGHT CENTER, BELTSVILLE, MD.

IN ITS program to encourage lunar science, the National Aeronautics and Space Administration held a conference last winter in Washington on problems of lunar research and certain related topics in the physics of meteorites. The meeting was organized by the Theoretical Div. of the NASA Goddard Space Flight Center as one of a continuing series of seminars on current theoretical problems in the space sciences. The participants included a representative national group of geologists and geophysicists and a number of astronomers, physicists, and chemists with an interest in the moon. As the study of lunar science is gaining momentum, we would like to bring the highlights of this conference to your attention.

Origin of the Meteorites

Harold C. Urey of the Univ. of California began the conference with arguments for the hypothesis that certain types of meteorites must come from an object such as the moon. According to Urey, it is significant that the cosmic-ray ages of the stoney meteorites are only some tens of millions of years, whereas the cosmic-ray ages of the iron meteorites run in the neighborhood of one billion years. The cosmic-ray age of a meteorite is obtained from the measurement of the ratio of Helium 3 to Helium 4 in the meteorite, and is a measure of the time that this object has been bombarded by cosmic rays in space. Calculations by E. Opik of the Univ. of Maryland have demonstrated that an object moving in the asteroidal belt may be expected to collide with the earth in a time between some hundreds of millions and one billion years. On the other hand, a meteorite moving in an orbit near that of the earth is calculated to have a lifetime for collision with the earth of the order of only 10 million years. Opik's results therefore tend to support the hypothesis that the iron meteorites (CONTINUED ON PAGE 72)

The Ambassador Hotel in Los Angeles, scene of the 1960 ARS Semi-Annual Meeting May 9–12.

On to Los Angeles

Semi-Annual Meeting, marking 30th anniversary of ARS, shapes up as one of the largest ever . . . 29 Technical Sessions planned . . . Seifert, Ostrander, Old to speak . . . Astronautical exposition a sellout

This year's Semi-Annual Meeting, scheduled for May 9–12 at the Ambassador Hotel in Los Angeles, will mark the 30th anniversary of the American Rocket Society. Reflecting the Society's growth during the past few years, the meeting will be the second largest in ARS history, exceeded in size only by the 1959 Annual Meeting, with 30 Technical Sessions as against the 29 scheduled for Los Angeles.

The preliminary program for the meeting lists 106 unclassified paper titles and, with the additional papers still to be announced, the total could come close to the 132 unclassified papers presented at the Annual Meeting.

Project Tiros Session

Highlights of the meeting will be an all-day session on Project Tiros; a panel which will discuss the merits of launchers for mobile and hardbase missile installations; a classified session on the comparative capabilities of liquid and solid rocket engines; and an evening session on latest events in spaceflight. An invitation has again been extended to the Soviet Union to send representatives to the meeting and present papers at different sessions.

Luncheon addresses will also be a focal point of interest. ARS President Howard S. Seifert will speak at the Monday luncheon; on Tuesday, the newly appointed director of the NASA Office of Launch Vehicle Programs, Maj. Gen. Donald Ostrander, will speak; while Bruce S. Old, vice-president of Arthur D. Little, will speak on "Pentagon for Progress" at the Wednesday luncheon. The latter is an outgrowth of the ADL survey of research programs.

In addition to the technical presentations at the meeting, there will also be another sellout Astronautical Exposition with exhibits from 64 companies (see pages 48–49) and another in the highly successful series of ARS Marketing Symposiums.

The complete program for the Semi-Annual Meeting appears on the following pages.

LUNCHEON SPEAKERS

Howard Seifert

Maj. Gen. D. Ostrander

Bruce S. Old

SUNDAY, MAY 8

6:00–8:00 p.m. **Cocoanut Grove**

(Admission by registration badge)

Mixer

Sponsored by the ARS Corporate Members listed on page 50 under heading Reception.

MONDAY, MAY 9

Hypersonics

9:00 a.m. **Colonial Room**

Chairman: Alfred J. Eggers, National Aeronautics and Space Administration, Ames Research Center, Mountain View, Calif.

✦Shock Wave and Flow Field Development in Hypersonic Re-Entry, Ronald F. Probstein, Brown Univ., Providence, R.I. (1110-60)

✦Similarity Solutions for Inviscid Hypersonic Flow Over Slender Power Law and Related Bodies, Harold Mirels, National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio. (1111-60)

✦Three Dimensional Inviscid Hypersonic Flow, Richard Scheuing, Grumman Aircraft Engineering Corp., Bethpage, N.Y. (1112-60)

Missiles and Space Vehicles

9:00 a.m. **Cocoanut Grove**

Chairman: Richard De Lauer, Space Technology Laboratories, Los Angeles, Calif.

✦Optimum of 24-Hour Equatorial Orbit, A Fuil and H. Brahm, Space Technology Laboratories, Los Angeles, Calif. (1120-60)

✦Lunar Landing Vehicle Requirements J. R. Wrobel, and R. R. Breshears, Jet Propulsion Laboratory, Pasadena, Calif. (1121-60)

✦Problems Associated with Multiple Starts of Space Craft, W. F. Radcliffe and J. R. Transue, Convair-Astronautics, San Diego, Calif. (1122-60)

✦High-Energy Propellant Comparisons for Space Missions. R. V. Burry J. Jortner, and J. K. Rosemary, Rocketdyne, North American Aviation, Inc., Canoga Park, Calif. (1123-60)

Lunar Exploration

9:00 a.m. **Embassy Room**

Chairman: Herbert Friedman, U.S. Naval Research Laboratory, Washington, D. C.

✦Survey of Current Knowledge of the Moon, Robert Jastrow, National Aeronautics and Space Administration, Washington, D. C. (1114-60)

✦Vehicle Requirements for Lunar Exploration, Ernst Stuhlinger, Army Ballistic Missile Agency, Huntsville, Ala. (1115-60)

✦Surface Structure and Composition of the Moon, J. R. Arnold, Univ. of California, La Jolla, Calif. (1117-60)

✦Lunar Seismological Experiment, Frank Press, California Institute of Technology, Seismological Laboratory, Pasadena, Calif. (1118-60)

✦Experiments Related to the Internal Structures of the Moon, J. G. F. MacDonald, National Aeronautics and Space Administration, Washington, D.C. (1119-60)

Human Factors Considerations in Maintainability and Trouble Shooting

9:00 a.m. **Venetian Room**

Chairman: Stan Deutsch, Douglas Aircraft Co., Santa Monica, Calif.

✦The Role of Man in the Maintenance of Earth Satellites, David Meister, Convair-Astronautics, San Diego, Calif. (1214-60)

✦Space-Borne Maintenance of Electronic Equipment Compared with Current Procedures for Maintaining Airborne Electronics Equipment, Richard W. Highland, Hughes Aircraft Co., Culver City, Calif. (1215-60)

✦Monitoring of Dynamic Status of Advanced Space Vehicle Displays, Rutledge L. Jay, Douglas Aircraft Co., Santa Monica, Calif. (1216-60)

✦Evaluation of an Experimental Trouble Shooting Guide, John Whittenburg, Human Sciences Research, Washington, D.C. (1217-60)

✦Maintaining Space Vehicles, Nicholas A. Bond, Dunlap & Associates, Santa Monica, Calif. (1218-60)

Luncheon

12:30 p.m. **Cocoanut Grove**

Toastmaster: William L. Rogers, President, ARS Southern California Section.

Speaker: Howard S. Seifert, President, American Rocket Society.

Human Factors

2:30 p.m. **Cocoanut Grove**

Chairman: Laurel van der Wal, Space Technology Laboratories, Los Angeles, Calif.

Vice-Chairman: A. Bialecki, Electric Boat Div., General Dynamics Corp., Groton, Conn.

✦Submarine Air Revitalization, A. Bialecki, Electric Boat Div., General Dynamics Corp., Groton, Conn. (1223-60)

✦Normal Environment in Airborne Laboratories, Lt. Comdr. Victor Prather, Office of Naval Research, Washington, D.C. (1224-60)

✦Some Practical Reliability Problems in Recoverable Bio-Satellite Instrumentation, Capt. Bruce Pinc, Air Force Ballistic Missile Div., Bio-astronautics Directorate, Los Angeles, Calif. (1225-60)

✦Design and Maintainability of the Able-Baker Capsules, W. G. Kistler, Army Ballistic Missile Agency, Bioastronautics Research Office, Huntsville, Ala. (1226-60)

✦Life Support Systems for the Lunar Base, James G. Gaume, The Martin Co., Denver, Colo. (1227-60)

Ion and Plasma Propulsion

2:30 p.m. **Venetian Room**

Co-Chairmen: Rolf Buhler, Giannini Plasmadyne Corp., Santa Ana, Calif., and Nathan W. Snyder, Advanced Research Projects Agency, Washington, D.C.

✦Voltage-Current Characteristics of Tungsten Electrodes in Cesium Vapor, L. H. Stauffer, General Electric Engineering Laboratory, Schenectady, N. Y. (1124-60)

✦Design and Performance of Small Model Ion Engines, G. R. Brewer, J. E. Etter, and J. R. Anderson, Hughes Research Laboratories, Culver City, Calif. (1125-60)

✦NASA Experimental Research with Ion Rockets, E. E. Dangle and D. L. Lockwood, Lewis Research Center, National Aeronautics and Space Administration, Cleveland, Ohio. (1126-60)

✦Experimental Studies of Cesium Ion Rocket Performance, R. N. Edwards, P. E Jasper, G. Kuskevics, and R. A Scheffer, Flight Propulsion Laboratory, General Electric Co., Cincinnati, Ohio. (1127-60)

Hypersonics

2:30 p.m. **Embassy Room**

Chairman: George E. Solomon, Space Technology Laboratories, Los Angeles, Calif.

✦Recent Soviet Work in Hypersonic Flow Theory, Wallace D. Hayes, Princeton Univ., Princeton, N.J. (1129-60)

✦Aerodynamic Stability at Ultra-High Altitude, S. A. Schaaf, G. J. Maslach, G. Maulic, and M. Chahine, Univ. of California, Berkeley, Calif. (1130-60)

✦Recent Hypersonic Studies of Wings and Bodies, Mitchel H. Bertram and Arthur Henderson Jr., National Aeronautics and Space Administration, Langley Research Center, Va. (1131-60)

✦High Temperature Rarefied Ultra-High Mach Number Flow Over a Flat Plate, Henry T. Nagamatsu and R. E. Sheer Jr., General Electric Research Laboratory, Schenectady, N.Y. (1132-60)

Propellants and Combustion

2:30 p.m. **Colonial Room**

Chairman: Melvin Gerstein, Lewis Research Center, National Aeronautics and Space Administration, Cleveland, Ohio.

✦The Catalytic Decomposition of Ammonium Perchlorate, A. Hermoni and A. Salmon, Technion, Israel Institute of Technology, Haifa Israel. (1107-60)

✦On the Importance of Combustion-Chamber Geometry in High-Frequency Oscillations in Rocket Motors, J. R. Osborn and J. M. Bonnell, Purdue Univ., Lafayette, Ind. (1108-60)

✦A Two-Wavelength Interferometric Technique for the Study of Heat and Mass Transfer of Combustible Liquids, M. M. El-Wakil, Univ. of Wisconsin, Madison, Wis. (1109-60)

Latest Events in Spaceflight

8:00 p.m. **Embassy Room**

Chairman: Homer E. Newell Jr., National Aeronautics and Space Administration, Washington, D.C.

This session will be devoted to a review and discussion of the latest scientific determinations made from data gathered by current satellites, rockets, and probes—U.S. and Soviet.

TUESDAY, MAY 10

Magnetohydrodynamics

9:00 a.m. **Cocoanut Grove**

Chairman: Joseph Neuringer, Republic Aviation Corp., Farmingdale, N.Y.

✦Heat Transfer and Skin Friction in Magnetohydrodynamic Channel Flow, F. D. Hains, Boeing Airplane Co., Seattle, Wash. (1138-60)

✦On the Magnetogasdynamics of Compressible Vortices, James E. McCune and Coleman Du P. Donaldson, Aeronautical Research Associates of Princeton, Inc., Princeton, N.J. (1139-60)

✦On a Hydro-Electromagnetic, Osman Mawardi, Massachusetts Institute of Technology, Cambridge, Mass. (1140-60)

✦Electro-Gas-Dynamical Considerations of a Pulse Plasma-Pinch Engine, Alfred Kunen, William McIlroy, William Guman, and Irving Granet, Republic Aviation Corp., Farmingdale, L.I., N.Y. (1141-60)

Instrumentation for Combustion Stability Research

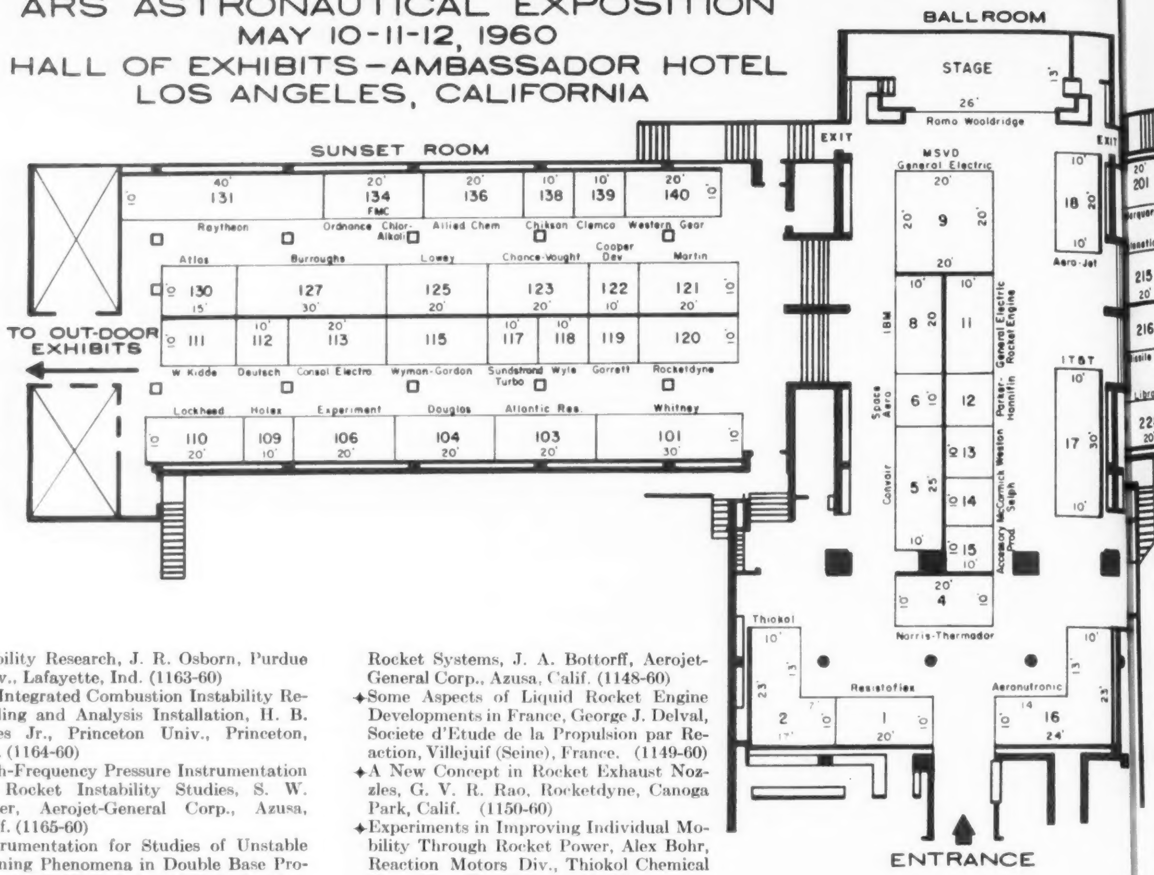
9:00 a.m. **Colonial Room**

Chairman: John E. Witherspoon, Rocketdyne, North American Aviation, Inc., Canoga Park, Calif.

✦Instrumentation for Research on Combustion Instability in Solid Propellant Rocket Motors, F. W. Spaid and Ellis M. Landsbaum, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. (1162-60)

✦Some Instrumentation for Combustion

ARS ASTRONAUTICAL EXPOSITION
MAY 10-11-12, 1960
HALL OF EXHIBITS—AMBASSADOR HOTEL
LOS ANGELES, CALIFORNIA



Stability Research, J. R. Osborn, Purdue Univ., Lafayette, Ind. (1163-60)

✦An Integrated Combustion Instability Recording and Analysis Installation, H. B. Jones Jr., Princeton Univ., Princeton, N.J. (1164-60)

✦High-Frequency Pressure Instrumentation for Rocket Instability Studies, S. W. Baker, Aerojet-General Corp., Azusa, Calif. (1165-60)

✦Instrumentation for Studies of Unstable Burning Phenomena in Double Base Propellants, G. W. Reissig and T. A. Angelus, Allegany Ballistics Laboratory, Hercules Powder Co., Cumberland, Md. (1166-60)

Hypersonics

9:00 a.m. **Venetian Room**

Chairman: Henry T. Nagamatsu, General Electric Research Laboratory, Schenectady, N.Y., and Rensselaer Polytechnic Institute, Troy, N.Y.

✦Dissociation Effects Upon the Compressible Turbulent Boundary Layer Skin Friction and Heat Transfer, William H. Dorrance, Convair Scientific Research Laboratory, San Diego, Calif. (1143-60)

✦Mass Injection Effect on the Hypersonic Interaction Problem, Ting Y. Li, Rensselaer Polytechnic Institute, Troy, N.Y. (1144-60)

✦The Aerothermodynamics of Long Re-Entry Trails, Madeleine and Robert Goulard, Bendix Products Div., Research Laboratory, South Bend, Ind. (1145-60)

✦Measured Pressure Distribution and Local Heat Transfer Rates for Flow Over Concave Hemispheres, C. Y. Koh and J. P. Hartnett, Univ. of Minnesota, Minneapolis, Minn. (1146-60)

Liquid Rocket Engines

9:00 a.m. **Embassy Room**

Chairman: Charles H. King Jr., Pratt & Whitney Aircraft, United Aircraft Corp., United, Fla.

✦Electrical Power from Rockets, John H. Huth, The Rand Corp., Santa Monica, Calif. (1147-60)

✦Ultra-Low Chamber Pressure Chemical Rocket Systems, J. A. Bottorff, Aerojet-General Corp., Azusa, Calif. (1148-60)

✦Some Aspects of Liquid Rocket Engine Developments in France, George J. Delval, Societe d'Etude de la Propulsion par Reaction, Villejuif (Seine), France. (1149-60)

✦A New Concept in Rocket Exhaust Nozzles, G. V. R. Rao, Rocketdyne, Canoga Park, Calif. (1150-60)

✦Experiments in Improving Individual Mobility Through Rocket Power, Alex Bohr, Reaction Motors Div., Thiokol Chemical Corp., Denville, N. J. (1151-60)

Luncheon

12:30 p.m. **Cocoanut Grove**

Toastmaster: Kurt Stehling, Head of Group, Rocket Vehicles Division, National Aeronatuics & Space Administration, Washington, D.C.

Speaker: Maj. Gen. Donald Ostrander, Director, Office of Launch Vehicle Programs, National Aeronautics & Space Administration, Washington, D.C.

Support Equipment for Mobile and Hard Launchers
(Panel—Secret)

2:30 p.m. **Embassy Room**

Chairman: Robert Kendall, Arthur D. Little, Inc., Cambridge, Mass.

Moderator: Frederick C. Durant III, Avco Research and Advanced Development, Wilmington, Mass.

✦Hard Base Launch Facilities in Relation to the Titan Missile Program, H. L. Cox, The Martin Co., Denver, Colo.

✦Ground Support Equipment Considerations for Railroad Type Mobile ICBM System, F. A. Jendrick, Boeing Airplane Co., Seattle, Wash.

✦Ground Support Aspects of a Submarine Launched Ballistic Missile, W. A. Fiedler, Lockheed Missile Systems Div., Sunnyvale, Calif.

✦Support Equipment for the Air Launched Ballistic Missile, Garland Osborn, Douglas Aircraft Co., Santa Monica, Calif.

Electrostatic Propulsion

2:30 p.m. **Venetian Room**

Chairman: Nathan W. Snyder, Institute for Defense Analyses, Advanced Research Projects Div., Washington, D.C.

✦Propulsion by Composite Beams of Negative and Positive Ions, M. H. Gilleo and S. W. Kash, Lockheed Missile Systems Div., Sunnyvale, Calif. (1157-60)

Effect of Electrode Refraction on Ion Beam Collimation, G. C. Baldwin, General Electric Engineering Laboratory, Evendale, Ohio. (1158-60)

✦Ion Erosion of Accelerating Electrodes, J. S. Luce, Oak Ridge National Laboratory, Oak Ridge, Tenn. (1159-60)

✦Space-Charge Measurements in Expanding Ion Beams, J. M. Sellen and H. Shelton, Ramo Wooldridge Div., Thompson Ramo Wooldridge, Inc., Canoga Park, Calif. (1160-60)

✦Neutralization Experiments on Broad Cesium-Ion Beams, H. Shelton and J. M. Sellen, Ramo Wooldridge Div., Thompson Ramo Wooldridge, Inc., Canoga Park, Calif. (1161-60)

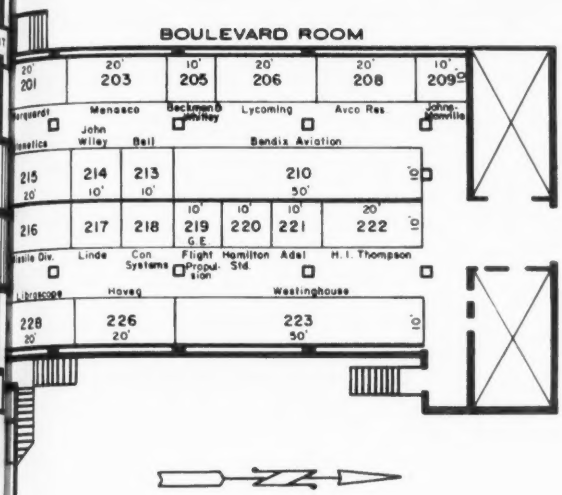
Solid Rockets

2:30 p.m. **Cocoanut Grove**

Chairman: H. L. Thackwell Jr., Grand Central Rocket Co., Redlands, Calif.

Vice-Chairman: Leonard Piasecki, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif.

✦The Hybrid Rocket Motor and Its Unique Capabilities, John Gustavson, Grand Central Rocket Co., Redlands, Calif. (1167-60)



✦Thrust Vector Control Nozzles for Solid-Propellant Engines, F. J. Rechin, Thompson Ramo Wooldridge Corp., Cleveland, Ohio. (1168-60)

✦The Design of Movable Nozzles, E. J. Hayes and S. F. Watanabe, Kelsey-Hayes Co., Detroit, Mich. (1169-60)

✦Temperature Gradients Across Solid Propellant Rocket Grains, J. C. Shumacher and J. H. Wilson, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. (1170-60)

✦Design and Flight-Test of Missile Powered by a Gimballed Motor, R. J. Blalock, Chance Vought Aircraft, Inc., Dallas, Tex. (1171-60)

Marketing Symposium

3:30 p.m. — Colonial Room

Capabilities of Liquid and Solid Rocket Propellant Engines (Panel—Secret)

8:00 p.m. — Embassy Room

Chairman: Y. C. Lee, Aerojet-General Corp., Azusa, Calif.

Paul R. Vogt, Rocketdyne, a division of North American Aviation, Inc., Canoga Park, Calif.; John C. Moise, Aerojet-General Corp., Sacramento, Calif.; Richard B. Canright, Douglas Aircraft Co., Santa Monica, Calif.; Joseph W. Wiggins, Thiokol Chemical Corp., Redstone Arsenal, Ala.; H. L. Thackwell, Grand Central Rocket Co., Redlands, Calif.; Ernest R. Roberts, Aerojet-General Corp., Sacramento, Calif.

WEDNESDAY, MAY 11

Guidance and Navigation

9:00 a.m. — Cocoanut Grove

Chairman: Donald P. LeGalley, Space Technology Laboratories, Los Angeles, Calif.

Vice-Chairman: Robert J. Parks, Jet Propulsion Laboratory, Pasadena, Calif.

✦Rudimentary Launch Guidance Methods for Space Missions, C. J. Pfeiffer, Jet Propulsion Laboratory, Pasadena, Calif. (1172-60)

✦Propagation of Errors in a Schuler-Type Inertial Navigation System, Joseph G. Gurley, Hughes Aircraft Corp., Culver City, Calif. (1173-60)

✦On the Adequacy of ICBM Guidance Capability for a Mars Launch, William N. Spence, Nortronics Div., Northrop Corp., Hawthorne, Calif. (1174-60)

✦Evaluation of Precision Gyros for Space-Boost Guidance Applications, L. K. Jensen and B. H. Evans, Space Technology Laboratories, Los Angeles, Calif. (1175-60)

✦An Investigation of a Terminal Guidance System for a Satellite Rendezvous, Neil J. Miemi, Chrysler Missile Div., Detroit, Mich. (1176-60)

Power Systems

9:00 a.m. — Venetian Room

Chairman: Eugene B. Zwick, Sundstrand Turbo Div., Pacoima, Calif.

✦A Review of WADD Solar Power Programs, William C. Savage, Wright Air Development Div., Wright-Patterson AFB Ohio. (1177-60)

✦Internal Design Considerations for Cavity-Type Solar Absorbers, Charles W. Stephens and Alan Haire, Electro-Optical Systems, Inc., Pasadena, Calif. (1178-60)

✦An Analysis of Mirror Accuracy Requirements for Solar Powerplants, David Silvern, Sundstrand Turbo Div., Pacoima, Calif. (1179-60)

✦Photochemistry and Space-Power Generation, James R. Pitts, Univ. of California, Riverside, Calif., and David Margerum, Sundstrand Turbo Div., Pacoima, Calif. (1180-60)

Space Observation Systems

9:00 a.m. — Embassy Room

Chairman: Sidney Sternberg, Radio Corporation of America, Princeton, N.J.

✦Tiros Meteorological Satellite, Sidney Sternberg, Radio Corp. of America, Princeton, N.J., and W. G. Stroud, National Aeronautics and Space Administration Washington, D.C. (1181-60)

✦Some Results Sought from Meteorological Satellite Systems, Sigmund Fritz, Dept. of Commerce, U.S. Weather Bureau, Washington, D.C. (1182-60)

✦Operations and Control Equipment of Tiros-1 Meteoro ogical Satellite, E. A. Goldberg and V. D. Landon, Radio Corp. of America, Princeton, N.J. (1183-60)

✦Aspects of Global Surveillance, J. Douglas Sailor, Lockheed Aircraft Corp., Sunnyvale, Calif. (1185-60)

✦Design Consideration for an Orbiting Astronomical Observatory, William C. Triplett, Ames Research Center, Moffet Field, Calif. (1184-60)

✦Scientific Experiments for Space Probes near the Earth, Mars, and Venus, Marcia Neugebauer, Jet Propulsion Laboratory, Pasadena, Calif. (1195-60)

Underwater Propulsion

9:00 a.m. — Colonial Room

Chairman: Charles S. Sanders, Bureau of Naval Weapons, Dept. of the Navy, Washington, D.C.

Vice-Chairman: Herman E. Sheets, General Dynamics Corp., Groton, Conn.

✦Hydrodynamics and Propulsion of Submerged Bodies, George F. Wislicenus, The Pennsylvania State University, University Park, Pa. (1186-60)

✦Factors Influencing the Size and Weight of Underwater Vehicles, Robert C. Brumfield, U.S. Naval Ordnance Test Station, Pasadena, Calif. (1187-60)

✦Some Aspects of Underwater Jet Propulsion Systems, Calvin A. Gongwer, Aerojet-General Corp., Azusa, Calif. (1188-60)

✦An Introduction to the Selection of High Performing Propellants for Torpedoes, Leonard Greiner, Experiment, Inc., Richmond, Va. (1189-60)

Luncheon

12:30 p.m. — Cocoanut Grove

Toastmaster Tom B. Carvey Jr., General Chairman, ARS Semi-Annual Meeting.

Speaker Bruce S. Old, Vice-President, Arthur D. Little, Inc., Cambridge, Mass. Subject "Pentagon for Progress."

Space Observation Systems

2:00 p.m. — Embassy Room

Chairman Sidney Sternberg, Radio Corporation of America, Princeton, N.J.

✦Limitations on Satellite Spotting from Space Platforms, A. Robinson, Douglas Aircraft Co., El Segundo, Calif. (1142-60)

✦Observations for Lunar Landing Vehicles, H. Hartbaum, ABMA, Huntsville, Ala. (1213-60)

✦Photography of the Moon From Space, Amrom H. Katz, The Rand Corp., Santa Monica, Calif. (1196-60)

✦Lunar Observation Systems, Paul L. Wickham, Missile Development Div., North American Aviation Inc., Downey, Calif. (1197-60)

✦Error Analysis Considerations for a Satellite Rendezvous, William Duke, et al., Space Technology Laboratories, Los Angeles, Calif. (1918-60)

✦Electrostatic Tape Camera for Scientific Satellite Inspection, S. Spaulding, Radio Corp. of America, Princeton, N.J. (1199-60)

Space Law and Sociology

2:30 p.m. — Colonial Room

Chairman: James S. Hanrahan, Chief, Historic Div., AFMDC, Holloman AFB, N.M.

Vice-Chairman: Andrew G. Haley, General

Counsel, American Rocket Society, Washington, D. C.

- ✦The Transformation from Aviation to Aerospace in Industry: Economic Implications of the Age of Space, Dr. David Bushnell, AFDMC, Holloman AFB, N.M. (1190-60)
- ✦The Negative Reactions to the Age of Space, James S. Hanrahan, AFDMC, Holloman AFB, N.M. (1191-60)
- ✦The Extraordinary Administrative Radio Conference of 1963 to Allocate Frequency Bands for Space Radio-Communication Purposes, Andrew G. Haley, General Counsel, American Rocket Society, Washington, D.C. (1192-60)
- ✦The Sociology of Power Technology and Its Implications in the Space Age, William C. Lawton, Univ. of Arizona, Tucson, Ariz. (1193-60)
- ✦Law and the Political Setting, Howard J. Taubenfield, Golden Gate College, San Francisco, Calif. (1194-60)

Power Systems

2:30 p.m. **Venetian Room**

Chairman: Eugene B. Zwick, Sundstrand Turbo Div., Pacoima, Calif.

- ✦Meteoroids Ve sus Space Vehicles, Robert Bjork, The Rand Corp., Santa Monica, Calif. (1200-60)
- ✦Conversion of Heat to Electricity in Solids and Plasmas, Werner Teutsch, General Atomics, Div. of General Dynamics Corp., San Diego, Calif. (1201-60)
- ✦Analysis and Design of Partial Admission Axial Impulse Turbines, Hans D. Linehardt, and D. H. Silvern, Sundstrand Turbo Div., Pacoima, Calif. (1202-60)
- ✦The Snap-11 Nuclear Space Power, Joseph R. Wetch, Donald J. Cockeram, and Herman M. Dieckamp, Atomics International, Div. of North American Aviation, Inc., Downey, Calif. (1203–60)

Nuclear Propulsion Instrumentation and Controls

2:30 p.m. **Cocoanut Grove**

Chairman: A. R. Crocker, General Electric Co., Idaho Falls, Idaho.

Vice-Chairman: Andrew Koonce, Los Alamos Scientific Labs., Los Alamos, N.M.

- ✦Evaluation of Kiwi A Instrumentation System, Bryant L. Hanson, Edgerton Germeshausen and Grier, Inc., Las Vegas, Nev. (1204-60)
- ✦Project Rover Static Test Instrumentation, Percival Gates, Edgerton Germeshausen and Grier, Inc., Las Vegas, Nev. (1205-60)
- ✦Radiation Effects Data Acquisition System, D. G. Egan, Convair, Fort Worth, Tex. (1206-60)
- ✦Tory 11-A Instrument System, C. Barnett, H. McDonald, and P. Uthe, Univ. of California Lawrence Radiation Laboratory, Livermore, Calif. (1207-60)
- ✦Tory 11-A Reactor Control System Developments, Robert E. Finnigan, Univ. of California Lawrence Radiation Laboratory, Livermore, Calif. (1208-60)

Reception

6:00 p.m. **Poolside**

(For those holding banquet tickets)

Sponsored by the following ARS Corporate Members: Aeroscience, Inc.; American Potash & Chemical Corp.; Coleman Engineering Co., Inc.; Convair-Pamona; Douglas Aircraft Co., Inc.; The Firestone Tire & Rubber Co; The Garrett Corp; Genisco, Inc.; Giannini Plasmadyne Corp.; Grand Central Rocket Co.; Hoffman Electronics Corp.; Hughes Aircraft Co.; Hughes Tool Co.; Lockheed Aircraft Corp.; The Marquardt Corp.; North American Aviation, Inc.; Pacific Automation Products, Inc.; The Ralph M. Parsons Co.; Robbins Aviation, Inc.; Servomechanisms, Inc.; Space Technology Laboratories, Inc.; Telecomputing Corp; H. I. Thompson Fiber Glass Co.; Thompson Ramo Wooldridge, Inc.; Western Gear Corp., Wyle Laboratories.

30th Anniversary Banquet

7:00 p.m. **Embassy Room**

Toastmaster: G. Edward Pendray, Founding Member, and Past President, American Rocket Society.

Thursday, May 12

Nuclear Propulsion

9:00 a.m. **Embassy Room**

Chairman: Raemer Schreiber, Los Alamos Scientific Laboratory, Los Alamos, N.M.

- ✦Fluidized Solids as a Nuclear Fuel for Rocket Propulsion, L. P. Hatch, W. H. Regan, and J. R. Powell, Brookhaven National Laboratory, Upton, N.Y. (1209-60)
- ✦Rocket Propulsion with Nuclear Power, E. L. Resler Jr. and N. Rott, Cornell Univ., Ithaca, N.Y. (1210-60)
- ✦Reactor Heat Removal Limitation for Nuclear Rockets, G. Yasui, Lockheed Missile and Space Div., Sunnyvale, Calif. (1211-60)
- ✦The Combo Space Propulsion System—Feasibility Study, David L. Cochran, Aerojet-General Nucleonics, San Ramon, Calif. (1212-60)

Astrodynamics

9:00 a.m. **Venetian Room**

Chairman: Louis G. Walters, Aeronutronic, A Div. of Ford Motor Co., Newport Beach, Calif.

- ✦A General Survey of the Problem of Optimizing Flight Paths of Aircraft and Missiles, Angelo Miele, Boeing Scientific Research Laboratory, Boeing Airplane Co., Seattle, Wash. (1219-60)
- ✦Orbit Determination from Range and Range-Rate Data, Robert M. L. Baker Jr., Ballistic Missile Div., Air Research and Development Command, Los Angeles, Calif. (1220-60)
- ✦The Artificial Earth Satellite—A New Geodetic Tool, Bruce C. Murray, Air Force Cambridge Research Center, Air Research and Development Command, Bedford, Mass. (1221-60)
- ✦Motion of an Orbiting Vehicle About Its Mass Center Due to the Gravity Gradient, J. P. King, Jr., General Electric Co., Missile and Space Vehicle Dept., Philadelphia, Pa. (1222-60)

Astrodynamics

2:30 p.m. **Venetian Room**

Chairman: Robert M. L. Baker Jr., Ballistic Missile Div., Air Research and Development Command, Los Angeles, Calif.

- ✦Propulsion Requirements for Controllable Satellites, Theodore N. Edelbaum, United Aircraft Corp., Research Dept., East Hartford, Conn. (1228-60)
- ✦The Station Keeping Implications of an Artificial Satellite, Paul E. Koskela, Lawrence Nicola, and Louis G. Walters, Aeronutronic, a Div. of Ford Motor Co., Newport Beach, Calif. (1229-60)
- ✦Gradient Theory of Optimal Flight Paths, Henry J. Kelly, Grumman Aircraft Engineering Corp., Bethpage, N.Y. (1230-60)
- ✦Planar Motors About an Oblate Planet, Maurice L. Anthony and George E. Fosdick, The Martin Co., Denver, Colo. (1231-60)
- ✦The Choice of Unperturbed Orbit in the Use of Encke's Method for the Effects of Oblateness and Drag, Norman S. Hall and H. G. Gawlowicz, Defense Systems Dept., General Electric Co., Syracuse, N.Y. (1232-60)

Education

2:30 p.m. **Colonial Room**

Chairman: F. C. Lindvall, California Institute of Technology, Pasadena, Calif.

- ✦A Philosophy of an Engineering Curriculum for Undergraduates, L. M. K. Boelter, Univ. of California, Los Angeles, Calif. (1233-60)
- ✦Mathematics as a Liberal Art, Scott Buchanan, Fund for the Republic, Santa Barbara, Calif. (1234-60)
- ✦The Role of Analysis and Synthesis in Undergraduate Engineering Curriculum, Andrew A. Fejer, Illinois Institute of Technology, Chicago, Ill. (1235-60)
- ✦The Demands on Breadth of E. E. Curriculum, John G. Truxall, Polytechnic Institute of Brooklyn, Brooklyn, N.Y. (1237-60)
- ✦The Role of Engineering Analysis Courses in Engineering Education, D. W. ver Planck, General Atomic Div. of General Dynamics Corp., San Diego, Calif. (1238-60)

FRIDAY, MAY 13

Field Trips

No. 1 **8:00 a.m.**

Edwards AFB Rocket Test Center (Secret)

The visit will include a tour of the Edwards Air Force Base Rocket Test Center including the Minuteman silo, the large-scale thrust stand, a special environmental test stand, and certain other component test facilities. Scheduled for return at 4:30 p.m. The trip will be limited to 160 members.

Transportation: $2.25

No. 2 **8:15 a.m.**

Rocketdyne Field Laboratory

The visit will include a tour of the North American Aviation Santa Susana test laboratory. Experimental firings of varius components are planned and a full-scale engine firing will be included if possible. Scheduled for return by 1:00 p.m. This visit will be unclassified but is limited to 160 people.

Transportation: $1.25

No. 3 **8:30 a.m.**

North American Aviation, Inc. B-70 Mockup (Secret)

Visit will include a tour of the full-scale B-70 mockup and secondary exhibits. A brief presentation will be given on the capabilities of the B-70 as a missile launching platform. An advanced manufacturing techniques display is also included.

Return by noon. The trip will be limited to 160 members.

Transportation: $1.25

SPECIAL FIELD TRIPS AND LADIES PROGRAM

Monday, May 9

Tour A (Ladies Only) **12:00 noon**

Fashion Show and Luncheon

Bullock's Wilshire will feature the latest in summer fashions (location within walking distance of the Ambassador).

Cost, including luncheon: $3:00

(CONTINUED ON PAGE 68)

Mercury Tape Recorder

(CONTINUED FROM PAGE 44)

conditions specified. McDonnell Aircraft cautioned, however, that rubber-stamped part numbers, identification paints or dyes (even on rivets and bolts), or pressure-sensitive identification tapes could not be used and that all metal parts had to be vapor-degreased.

On the other hand, nonmetallic and nonceramic materials were a problem. Most manufacturers had specifications of the effect of temperature, but had not tested materials in a 100 percent atmosphere, a condition they had probably not anticipated.

McDonnell's materials and processes engineering group had conducted tests to determine objectionable-odor, toxicity, oxidation-resistance, and spontaneous-fire characteristics of various materials at temperatures of 160, 250, 300, and 400 F, and they made available their evaluations, which identified approved materials.

In many cases, however, the specialized demands of accurate tape recording in the stipulated environment or unusual operating conditions created by the recorder itself eliminated certain basic materials that passed McDonnell's tests.

A factor on which no information was available was the effect of pure oxygen on the parts and materials of the recorder equipment. This Datalab had to explore in its own research and testing program.

Major Problem Area

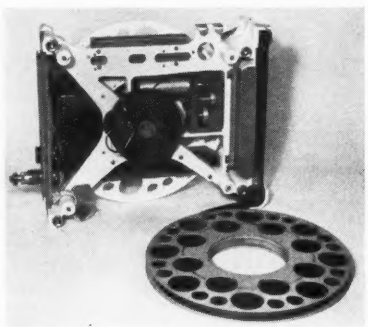
One major problem area that would not have arisen in extreme environmental operation without the oxygen atmosphere involved the common motors used to drive capstans and reels.

By running a 28-v DC motor continuously for two days in a bag inflated with pure oxygen, we confirmed, as suspected, that the motor emitted ozone, which could not be tolerated, but that the unusual amount of oxygen did not cause brush wear or arcing of governor contacts. In fact, the motor was reassembled after a teardown inspection, and run for another 700 hr.

As it was, the motor could easily be isolated to prevent ozone from contaminating the capsule's oxygen. The real problem came from the effect of the ozone on the nonmetallic materials in drive belts that had to share this isolation. For instance, neoprene and polyethylene in various combinations with other rubber or petrochemical products were affected by the ozone concentration that would build up. Also, various other materials were known either to be inadequate at high temperature or not to maintain the precise length needed for accurate drive of the recorder reels.

The materials that finally proved adequate were nylon webbing impregnated with silicone rubber which vulcanized at room temperature. The nylon resisted stretch and the impregnation exhibited the required compatibility with the environment. The drive belts, which have been made by hand, are $^3/_{16}$ in. wide and 4 in. long. They retain their length within 0.015 in. The belts that were not in the motor encapsulation, and were not subjected to ozone, were made of dacron and neoprene.

During the search for a material for the two covers that shield the tape recorder, each possible thermoset plastic was eliminated. Some materials that in themselves did not tend to start fires or explosions, such as polyesters, proved to burn quite easily. Other materials failed when tested somewhat above the 200 F temperature. (To insure reliability, Datalab allowed a safety factor in its own specifications.) Phenolic and glass cured at 450 F were eliminated because tooling and fabrication techniques would have involved late delivery.



Above, the recorder with case absent and one reel off reveals transistorized recording electronics, encapsulated motor, and pulley box. Production units do not have an open pulley box, as shown here in this experimental model. Below, the encased recorder, which weighs 12 lb.

After testing all thermoset plastics, it was finally decided to settle on a ductile aluminum alloy, Tens-50, formed by a vendor under license from North American Aviation. All metal parts were anodized for corrosion resistance.

This metal cover and all metal parts in the recorder had to be painted. The selection of paint created still more problems. Baked and air-dry silicones were specified by the contractor, but the heat-treated cast magnesium framework of the recorder warped and annealed at the 500 F temperature required to cure the paint. Moreover, air-dry silicone exhibited poor qualities of abrasion resistance. Air-dry silicone was taken at first; but as a result of Datalab's further research and testing, McDonnell approved epoxy paint, which has now proved satisfactory in all respects. Printed circuit boards have been dipped in epoxy so that the components will not come into contact with the oxygen atmosphere.

All materials that might pollute the Astronaut's precious atmosphere were thoroughly tested. At the same time, engineers were making imaginative use of approved materials and metals to develop a recorder that would exhibit greatest strength, recording accuracy, and reliability in the smallest possible package.

As to mechanical design, a major innovation was a "sandwich" construction: Takeup and supply reels were mounted on opposite sides of a main magnesium casting. Magnesium was chosen because it is more rigid than aluminum, besides being lighter.

Sandwich Design Advantages

The sandwich design offered several major advantages:

1. In addition to a package with smaller dimensions from the top view, the sandwich design actually made possible a thinner and lighter package. This is because the capstan motor, which is the longest component in the assembly, could be placed parallel to the top and bottom surfaces.
2. Its short coupled reel support had less tendency to bend under dynamic conditions.
3. It eliminated counterrotating reel shafts; smaller reel shafts could be used, resulting in reduced bearing sizes and proportionately less friction.
4. It made possible the use of hollow 4-in.-diam reel hubs for packaging reel-drive and brake mechanisms. In conventional recorders, with reels adjacent to each other, the hub area cannot be utilized for this purpose.

An initial concept was to couple the capstan drive motor (governed at 10,000 rpm) to a precision speed reducer which would then drive the two cap-

stans differentially. During tests, however, the speed reducer exhibited a slight backlash which contributed to flutter under dynamic conditions. This led to designing a three-stage reduction pulley box, utilizing belts. In this design, the normal speed of 1 $^7/_8$ ips can be changed to 15 ips by changing belts. The pulley arrangement gives efficiencies better than 95 percent at 1 $^7/_8$ ips. Wow and flutter under dynamic conditions are as low as 1 percent peak-to-peak at 1 $^7/_8$ ips.

Two motors are used—a capstan drive and a reel drive. The reel motor is identical to the capstan motor except that it lacks a governor. Both motors are encapsulated except for the drive shafts.

Differential capstans provide a constant tape tension across the magnetic head. The captstan on the takeup side revolves at a speed 1.0 percent greater than that of the supply capstan.

Power consumption was minimized by the use of specially designed "wrap-around" dual capstans. The tape wraps around 270 deg of the capstan to obtain driving friction, and thus eliminates the customary solenoid-actuated pinch rollers. Elimination of pinch-roller components reduced weight and favored precise tape tracking, because of the absence of pinch-roller tape deformation.

The recorder weighs 12 lb and requires less than 8 watts of power. It measures only 11 x 13 x 3 $^5/_8$ in. complete with electronics.

The Mercury capsule tape recorder will provide on seven data channels a complete analog record of phenomena occurring on the historic series of flights. Of these seven channels, one will be the voice comments of the Astronaut and the other six will be multiplexed data on capsule systems, events, and environmental conditions—such as temperature, pressure, acceleration, shock, and physiological changes in the Astronaut, as detected by sensitive pickups taped to his body.

Seven Data Channels

The Mercury capsule tape recorder lends itself readily to commercial applications. Operation of this recorder on 3 watts of power is possible by using high-efficiency DC motors. (These motors will not meet the severe environmental requirements, as do the present motors installed.) This means that batteries can be incorporated within the present recorder case without an increase in size. A rewind mechanism can be incorporated by installation of an additional motor. Also, playback electronics and a speaker can be included within the present size.

For ground-station uses, five of these recorders can be installed in bookshelf fashion in a standard 19-in. rack panel, 11 inches high. Such a setup could provide 35 channels of recorded data; and by a cycling operation, it could give 280 hr of single-track recording at a tape speed of 1 $^7/_8$ ips.

The fact that the recorder will operate within the −15 to 200 F temperature range and not emit noxious or toxic odors, or contaminate an oxygen atmosphere, suggest its application in submarines, hospitals, or industrial areas where explosive atmospheres may be present. ♦♦

Stepping Stones to Space

Lined up outside Rocketdyne's Canoga Park factory, these thrust chambers tell a story of a decade's progress toward million-lb-thrust liquid engines for space vehicles. From left, chambers for 75,000-lb-thrust Redstone, 150,000-lb-thrust Jupiter, 60,000-lb-thrust Atlas (sustainer), 150,000-lb-thrust Thor, and 400,000-lb-thrust E-1 applied-research engine. Rocketdyne engineers static-fired the first large engine (over 50,000 lb thrust) of this family successfully on March 2, 1950, in its then rudimentary Santa Susana facilities.

Letter Symbols for Rocket Propulsion

"American Standard Letter Symbols for Rocket Propulsion" (Y10.14-1959) is now available at $1.50 a copy from the American Standards Association, 70 E. 45th St., New York, N.Y., or from ASME, 29 W. 39 St., New York 8, N.Y.

AEC Research Reports

The new edition of "Atomic Energy Commission Research Reports," listings of about 5000 unclassified documents in the Office of Technical Services collection acquired to January 1960, can be obtained free by requesting "AEC Research Reports Price List No. 33" from OTS, U.S. Dept. of Commerce, Washington 25, D.C.

Ultra-Precise Ball Bearings Developed at MIT

Ball bearings with tolerances of 20 millionths of an inch, or 10 times better than standard requirements, have been developed at the MIT Instrumentation Lab in a five-year team effort involving MIT, Barden Corp., and BMD and WADD. The bearings are used in gyros found in a number of ballistic missiles and nuclear submarines.

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ARS news

Attendance of 700 Marks GSE Conference in Detroit

DETROIT—The ARS Ground Support Equipment Conference held at the Statler-Hilton Hotel here March 23–25 drew an attendance of 700 people concerned with the present status of GSE, recent advances, and future trends.

The conference was unique in that technical sessions were held in the morning only, with the afternoons kept free for field trips to facilities in the Detroit area. One evening session was also held.

The meeting got off to a good start with a mixer on Tuesday evening, March 22, sponsored by Beaver Precision Products, Burroughs Corp., Chrysler Corp., Continental Aviation and Engineering Corp., Dearborn Machinery Movers Co., Electro Mechanical Products, Ford Motor Co., General Motors Corp., Kelsey-Hayes Co., Koebel Diamond Tool Co., Vickers, and Wyandotte Chemical Corp.

Michigan Gov. G. Mennen Williams formally opened the meeting the following morning, along with B. J. Meldrum of Chrysler, general chairman of the conference. ARS National President Howard S. Seifert got the technical portion of the meeting underway with a general introduction at a classified (Secret) session highlighted by Army, Navy, and AF reports on GSE problems and trends.

The Wednesday luncheon speaker was I. M. Levitt, director of the Fels Planetarium of the Franklin Institute in Philadelphia. Dr. Levitt's topic was "The Moon—Target for Tomorrow," and in his address he noted that every element necessary for the establishment of manned outposts on the moon was already present there. Dr. Levitt predicted a manned landing on the moon within 10 years and the establishment of a permanent lunar base within 20 years.

The afternoon was devoted to field trips to Chrysler's Michigan Ordnance Missile Plant and the Ford Scientific Laboratory, while the evening session was highlighted by an address by Homer J. Stewart, director of NASA's Office of Program Planning and Evaluation, on the space agency's future program and the GSE necessary to support the program.

Sessions on Thursday morning covered the second generation of GSE systems and advances in mechanical GSE systems. At the former, classified Secret, Army, Navy, and AF experts reviewed the Pershing, Polaris, and Minuteman GSE systems.

C. Stark Draper, director of the MIT Instrumentation Laboratory and chairman of the MIT Aeronautics and Astronautics Dept., was the luncheon speaker. In his address, he stressed the need for small, simple, mobile GSE systems, and warned against the dangers of overly complex, expensive, and heavyweight GSE. He pointed to the Polaris system as an example of what he thought could be accomplished, and added that reducing weapons and GSE to trailertruck size and weight would do the trick.

Field trips on Thursday took conference registrants to either the Detroit Arsenal or the GM Technical Center.

The banquet that evening, preceded by a reception sponsored by the same ARS corporate members who sponsored the mixer, drew a large turnout. Featured speaker at the banquet was Brig. Gen. Austin W. Betts, ARPA director, who spoke on "The Ballistic Missile and Space." Gen. Betts noted in his address that, while the Soviets had at least a two-year head start on us in the space race, our hope lies in the fact that we seem to be more intelligent about the use of space. Thus, while the Russians seem to be going in for splashy "firsts," related to their obvious advantage in large thrust levels, our program is more rational in terms of continuing payoff. He also expressed the certainty that Atlas "is

On the calendar

1960	
May 2–5	ISA Sixth National Flight-Test Symposium, San Diego, Calif.
May 3–5	IRE-AIEE Western Joint Computer Conference, San Francisco.
May 9–11	ISA Third National Power Instrumentation Symposium, San Francisco State College, Calif.
May 9–11	31st Annual Meeting of Aerospace Medical Assn., Americana Hotel, Bal Harbour, Miami Beach, Fla.
May 9–12	**ARS Semi-Annual Meeting and Astronautical Exposition, Ambassador Hotel, Los Angeles.**
May 9–12	ISA Instrument-Automation Conference and Exhibit, Civic Auditorium, San Francisco.
May 9–13	National Conference of Society of Photographic Scientists and Engineers, Miramar Hotel, Santa Monica, Calif.
May 11	Symposium on "Medicine in The Space Age," Statler-Hilton Hotel, New York, N.Y., sponsored by Medical Society of State of New York.
May 23–25	**ISA, ARS, IAS, AIEE National Telemetering Conference, Miramar Hotel, Santa Monica, Calif.**
May 24–28	Japanese Rocket Society 2nd International Symposium on Rocketry and Astronautics, University Club, Tokyo.
May 26–27	"Psychophysiological Aspects of Space Flight" Symposium, by invitation, School of Aviation Medicine, Aerospace Medical Center, Hilton Hotel, San Antonio, Tex.
June 1–3	6th Annual Radar Symposium, Univ. of Michigan Willow Run Laboratories, Ann Arbor, Mich.
June 15–17	1960 Heat Transfer and Fluid Mechanics Institute, Stanford Univ., Stanford, Calif.
June 20–23	AGARD Avionics Panel on Radio Wave Absorption, Athens, Greece.
June 25–July 5	AACC, ISA, ASME, IRE, AICHE 1st International Congress for Automatic Control, Moscow.
June 26–July 1	American Society for Testing Materials Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N.J.
July 10–22	Underwater Missile Engineering Seminar, Pennsylvania State Univ., University Park, Pa.
July 18–19	**ARS Propellants, Combustion, and Liquid Rockets Conference, Ohio State Univ., Columbus.**
July 21–27	3rd International Conference on Medical Electronics, sponsored by Institution of Electrical Engineers and International Federation for Medical Electronics, Olympia, London.
Aug. 8–11	American Astronautical Society Western National Meeting, Olympic Hotel, Seattle, Wash.
Aug. 8–12	AIEE 1960 Pacific General Meeting, El Cortes Hotel, San Diego, Calif.
Aug. 15–20	**11th International Astronautical Congress, Stockholm, Sweden.**
Aug. 15–26	Summer Institute on Nondestructive Testing, Sacramento State College, San Francisco.
Aug. 23–25	1960 Cryogenic Engineering Conference, Univ. of Colorado, Boulder, Colo.
Aug. 29–Sept. 2	The Combustion Institute 8th International Symposium on Combustion, CalTech, Pasadena, Calif.
Aug. 31–Sept. 7	10th International Congress of Applied Mechanics, Congress Bldg., Stresa, Italy.
Sept. 15–16	Annual Meeting of Armed Forces Chemical Assn., Sheraton-Park Hotel, Washington, D.C.
Sept. 21–25	Air Force Assn. National Convention and Aerospace Panorama, San Francisco.
Sept. 26–30	3rd ISA Instrument-Automation Conference and Exhibit, N.Y. Coliseum, N.Y.C.
Sept. 27–30	**ARS Power Systems Conference, Miramar Hotel, Santa Monica, Calif.**
Oct. 10–12	**ARS Human Factors and Bioastronautics Conference, Biltmore Hotel, Dayton, Ohio.**
Oct. 20–21	Hypervelocity Projection Techniques Conference, Univ. of Denver, Colorado.
Oct. 26–27	1960 Computer Applications Symposium sponsored by Armour Research Foundation, Morrison Hotel, Chicago.
Dec. 5–8	**ARS Annual Meeting and Astronautical Exposition, Shoreham Hotel, Washington, D.C.**

significantly more accurate than its Soviet competitor."

Technical sessions on Friday morning included a classified (Secret) session on advances in electrical GSE and a session in which Peter Weiser of STL presented the only paper (ARS Preprint No. 1082–60), an analysis of "Operational Design—The Relationship of GSE to the Weapon System."

The luncheon speaker was Maj. Gen. Ben I. Funk, commander, Hq., San Bernardino Air Material Area, AMC, Norton AFB, Calif., whose topic was "The Impact of GSE and its Effect on the Ballistic Missile Program." Gen. Funk stressed the need for simpler, more reliable GSE which could be produced more economically.

The field trip that afternoon was to the Burroughs Military Electronic Computer Div.

The conference, held under the direction of the ARS Logistics and Operations, and Test Facilities and Support Equipment Committees, received noble support from the ARS Detroit Section, headed by E. A. Nielsen of Chrysler.

All in all, the Detroit meeting added up to another in the highly successful series of ARS special subject conferences which got underway last year.

—Irwin Hersey

Amateur Rocketry Pamphlet Now Available from ARS

ARS has just published a pamphlet on amateur rocketry for youngsters which points out the dangers inherent in experimentation with rockets using explosive propellants, and pointing out some alternative nonhazardous experiments. The pamphlet, entitled "Open Letter to Amateur Rocketeers," is a reprint of the article by Peter Zimmerman which appeared in the February *Astronautics*. It is now being distributed to all ARS Sections and Student Chapters.

Quantity reprints, imprinted with the name of the sponsor, are available from ARS Headquarters. For additional information, write to: Pamphlet, American Rocket Society, 500 Fifth Ave., New York 36, N.Y.

ARS Members Help Man New Missile Cruiser

Two ARS members are in charge of the Terrier missile battery aboard the Navy's new guided missile cruiser, the USS Topeka, commissioned in March. The two members are Lt. Comdr. H. E. Davies and Lt. E. W. Hays. They also report that the two ARS publications have been made part of the ship's technical library.

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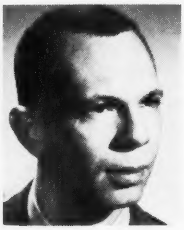
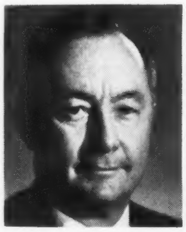
Seven New ARS Technical Committee Chairmen Named for 1960

Farrior



Goldsmith

Michelson



Nichols

Perchonok

Shafer

Wang

James S. Farrior is in charge of development of the flight control system and integration of the guidance system into the Polaris at Lockheed Missile and Space Div. His title is manager of guidance, Systems Div., Polaris Missile System. While at ABMA from 1951 to 1959, he was responsible for development of the Redstone, Jupiter, and Pershing guidance and control systems, as well as similar techniques for space projects, such as Jupiter C and Saturn.

Martin Goldsmith currently is working in the Propulsion Group of Rand Corp.'s Engineering Div. A recipient of a Guggenheim Jet Propulsion Fellowship while at CalTech in 1955, he had been a test engineer at NAMTC, Pt. Mugu, in 1951 and a research engineer at JPL in 1952. He joined Rand in 1955 to work on rocket propulsion.

Irving Michelson is professor and head of the Dept. of Aeronautical Engineering at Pennsylvania State Univ. From 1954 to 1957, when he came to Penn. State, he was doing research on aerodynamics, propulsion, and spaceflight at Odin Associates. Prior to that he had been engaged as a consultant aerodynamicist for NOTS and Rand Corp.

Peter L. Nichols Jr. heads the Propulsion Laboratory of Poulter Laboratories, which is a major division of Stanford Research Institute. He is also a consultant to the Office of the Asst. Secy of Defense, a member of the Senior Steering Committee for the Office of Ordnance Research, and a member of the Joint Army-Navy-AF Panel on Propellant Performance. He participated in the original work on polyurethane propellants in this country.

Eugene Perchonok, manager of Marquardt Corp.'s Advanced Engines Research Dept., is identified with early NACA ramjet activity, his pioneering experience dating back to 1945. He conceived and directed NACA experiments on supersonic application of the turbojet engine, and was later responsible for first tests at supersonic speeds of the J-79 engine installation in the B-58 Hustler.

John I. Shafer serves as a propulsion staff engineer to the laboratory director at Jet Propulsion Laboratory, where he has worked for the past 12 years as a research engineer and as chief of the Solid Rockets Section. From 1940 to the end of World War II, he worked for Hercules Powder Co. on development and production of single and double-base solid propellants.

C. J. Wang, manager of Space Technology Laboratories' Propulsion Systems and Development Dept., is well known for his work in gas dynamics, fluid mechanics, and chemical and nuclear propulsion. He is currently directing research and development in these fields at STL.

Chairman	Committee
Irving Michelson	Education
James S. Farrior	Guidance and Navigation
Martin Goldsmith	Liquid Rockets
C. J. Wang	Nuclear Propulsion
Peter L. Nichols Jr.	Propellants and Combustion
Eugene Perchonok	Ramjets
John I. Shafer	Solid Rockets

New ARS Standing Committee Chairmen

A. K. Oppenheim	Awards Committee
Howard S. Seifert	Executive Committee
Robert A. Gross	Finance Committee
W. L. Rogers	Membership Committee
William H. Pickering	Policy Committee
John L. Sloop	Program Committee
Alfred J. Eggers Jr.	Publications Committee
Col. John P. Stapp	Nominating Committee

Long Island Section Plans "Youth in Space" Program

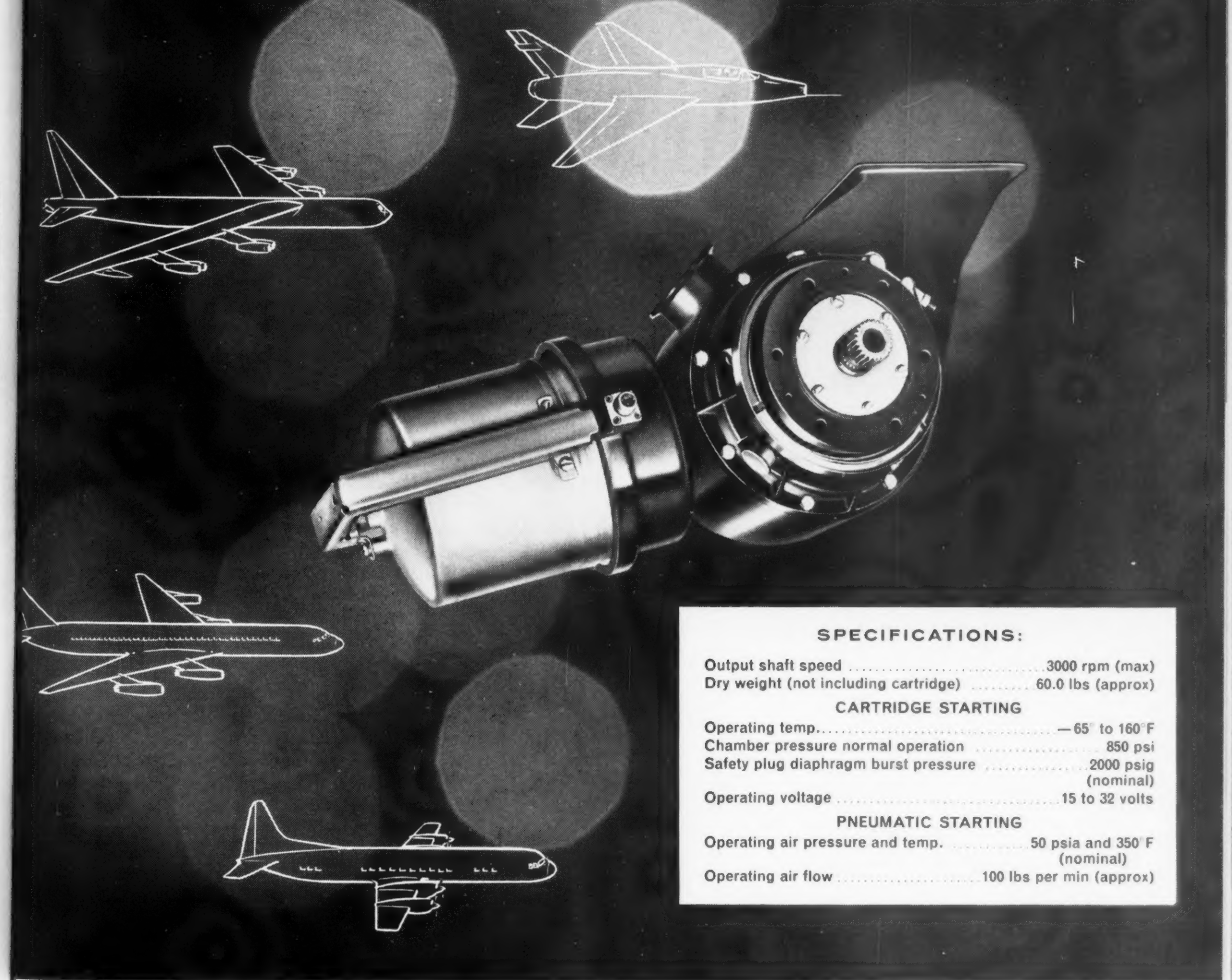
The ARS Long Island (N.Y.) Section has announced plans to stage a "Youth in Space" program as a top feature of the Science and Industry Exposition to be held at Roosevelt Exposition Center, L.I., October 14–15. Abelardo deAlcala, Section president, notes that the program will be designed to aid youngsters in planning careers and to demonstrate proper discipline for laboratory work in rocketry.

The Section invites all ARS members to assist its Program Committee in planning arrangements. Correspondence should be addressed to A. deAlcala, Arma Div., Old Country Rd., Garden City, N.Y.

ARS Film Library

ARS Headquarters is preparing a permanent film library and requests corporate members to submit films pertaining to our fields of endeavor to: Mr. Geoffrey Potter, Membership Manager, ARS, 500 Fifth Ave., N.Y. 36, N.Y.

The only operational cartridge starter...



SPECIFICATIONS:

Output shaft speed	3000 rpm (max)
Dry weight (not including cartridge)	60.0 lbs (approx)
CARTRIDGE STARTING	
Operating temp.	—65° to 160°F
Chamber pressure normal operation	850 psi
Safety plug diaphragm burst pressure	2000 psig (nominal)
Operating voltage	15 to 32 volts
PNEUMATIC STARTING	
Operating air pressure and temp.	50 psia and 350°F (nominal)
Operating air flow	100 lbs per min (approx)

AIRESEARCH'S CARTRIDGE/PNEUMATIC STARTER *has completed more than 20,000 successful cartridge starts for the F-100, F-105 and Hound Dog missile applications.*

Completely fail-safe, this lightweight package is the only cartridge starter capable of full containment of a wheel hub burst.

The AiResearch starter is extremely flexible and compact, making it easily adapted to any jet engine envelope. For example, the same starter now used on the Hound Dog missile can be delivered immediately for use on the B-52 itself.

This self-contained, aircraft-installed starting system provides quick, dependable starts in any climate or location by means of high temperature cartridge gases *or* low pressure air such as supplied by an AiResearch gas turbine serving as an onboard pneumatic power source or conventional ground support unit.

The starter consists, basically, of an air turbine starter and a removable solid propellant cartridge chamber. Combustion of the cartridge directs high pressure gas against the turbine wheel, turning the output shaft. Overspeed is controlled by aerodynamic braking action of air compressed by radial blades on the other side of the turbine wheel.

This simple system consists of proven components with many thousands of hours of successful operating history. The pioneer and leading manufacturer of air turbine starters of all types for both military and commercial application, AiResearch has more than four years of cartridge experience and 12 years' experience in pneumatic starters.

Your inquiries are invited.

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems and Components for: AIRCRAFT, MISSILE, SPACECRAFT, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

Three More Companies Become ARS Corporate Members

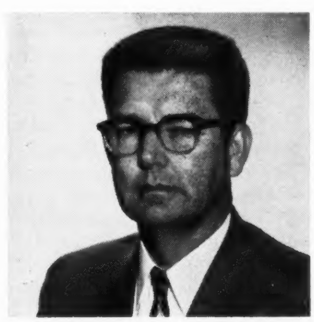
Three more companies have become corporate members of the American Rocket Society. The companies, their areas of activity, and those named to represent them in Society activities are:

Beckman Instruments, Inc., Systems Division, Anaheim, Calif., which will be represented by Robert J. Baumann, acting manager; Taylor C. Fletcher, director of research and engineering; Lawrence M. Silva, associate director of research and engineering; Frank J. Scheufele, marketing manager; and Anthony M. Johnson, assistant marketing manager.

Daniel, Mann, Johnson & Mendenhall, Los Angeles, Calif. As architects, engineers, and planners, DMJM designs ground-support facilities for rocket and missile propellant and instrumentation systems, missile training facilities, and research and development facilities. Named to represent the company are Marvin J. Kudroff, director of engineering; Jack R. Rummell, military projects director; Robert C. Westerfield, chief process engineer; David M. Fleming, assistant to the executive vice-president; and Thomas J. Carter, business development coordinator.

Reeves Instrument Corp., Garden City, N.Y., manufacturer of space-vehicle instrumentation systems and components, inertial guidance systems and components, radar tracking systems, and electronic computers. Representing the company are Rawley D. McCoy, vice-president, engineering; Sidney Godet, director of research; E. King Stodola, assistant to the president; Jack F. Lepre, vice-president, industrial relations; and J. Bryan Straley, executive vice-president.

TECHNICAL COMMITTEES



Brooks Morris, assistant director of Propulsion Div., Marquardt Corp., has been appointed Director of Technical

Committees, with the responsibility of supervising and coordinating the 22 ARS Technical Committees and making appointments to expired terms.

Education: Elliot Felt of Martin Co., head of the Panel on Educational Methods of the Committee, working on preparation of a detailed, coordinated lecture and educational program for youngsters which could be implemented by ARS Sections around the country, reports considerable progress. The Panel has reviewed the activities of 19 Sections in this area, and is now at work on a lecture series.

In addition, William E. Marshall, chairman of the Youth Activities Committee of the ARS Twin Cities Section, has forwarded to the Committee for review a proposal to organize Fuelless Rocket Clubs, which would use catapults, rather than explosive propellants, to launch model rockets. He has already prepared a brief talk and a 15-min playlet entitled "Operation Slingshot" to explain what could be accomplished by such clubs, and these were presented at a meeting of the Bloomington, Minn., PTA early in March. Both CAP and the Explorer Scouts have expressed interest in the proposal.

SECTION NEWS

Alabama: The Section recently elected new officers, who are as follows: Konrad K. Dannenberg, president; James B. Bramlet, vice-president; James W. Lee, secretary; and Gerald R. Guinn, treasurer.

Central Indiana: In February, the Section had the pleasure of hearing **A. H. Schwichtenberg,** head of the Dept. of Aerospace Medicine for the Lovelace Foundation, speak on "Space Medicine and the Selection of Astronaut Candidates." In March, **W. C. Cooley,** head of NASA's propulsion and auxiliary power unit program, spoke on "Space Power and Electrical Propulsion." The discussions of these guests were thoroughly enjoyed by the Section.

—**R. E. Sullivan**

Central Texas: The Section held regular meetings in January, February, and March, with 50, 90, and 65 members and guests at each, respectively. The January meeting was devoted chiefly to Section plans, and a movie was shown on the launching of the Atlas missile. At the February meeting, guest speaker **Col. John F. Brownlow Jr.,** USA, an executive officer of the 2nd Armored Div, presented an

1960 ARS Meeting Schedule

Date	Meeting	Location	Abstract Deadline
May 9–12	ARS Semi-Annual Meeting and Astronautical Exposition	Los Angeles, Calif.	Past
May 23–25	National Telemetering Conference	Santa Monica, Calif.	Past
July 18–19	Liquid Rockets and Propellants Conference	Ohio State Univ.	Past
Aug. 15–20	11th International Astronautical Congress	Stockholm, Sweden	Past
Sept. 27–30	Power Systems Conference	Santa Monica, Calif.	June 24
Oct 10–12	Human Factors and Bioastronautics Conference	Dayton, Ohio	July 1
Dec. 5–8	ARS Annual Meeting and Astronautical Exposition	Washington, D.C.	Aug. 25

Send all abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.

interesting review of the status of missiles used and planned for the Army. In March, guest speaker **Col. Paul A. Campbell,** of the USAF Aerospace Medical Center's advanced studies group, discussed the role of medicine in the missile and space field. He also described some experiments being conducted by the Air Force to provide information on conditions and problems in space.

—Frank R. Gessner Jr.

Chicago: S. W. Bradstreet of Armour Research Foundation spoke on "Composite Materials for Rockets and Missiles" at the January meeting of the Section. The great demand for heat-resistant nose cones and nozzles has led to the development of a large number of new materials. Both theoretical and experimental studies have resulted in techniques for combining these new materials into composites and fabricating them into useful shapes. The general principles by which the proper composites can be selected for specific tasks were aptly covered by Dr. Bradstreet, who characterized the available composites and demonstrated how their properties can be used to advantage in the solution of the crucial missile-materials problem.

—R. C. Warder Jr.

At a recent meeting, members of the Central Indiana Section look pleased as they prepare to dine and then hear an address by A. H. Schwichtenberg, head of the Department of Aerospace Medicine for the Lovelace Foundation, on space medicine and the selection of astronauts.

Members and guests of the Univ. of Michigan Chapter pose for a snapshot on their recent field trip to the Chrysler Missile Plant.

During National Engineer's Week, the San Diego Section joined other local chapters of technical societies in holding an exhibition at Convention Hall in Balboa Park. Above, their exhibit, based on photomurals and a scale model of the Titan launching complex made available through the courtesy of Ralph M. Parsons Co., Engineers and Consultants.

Florida: In March, the Section met in a classified session to hear a presentation on re-entry bodies. Guest speaker **Robert Crosby** of Lockheed Missiles and Space Div. discussed special problems involved in re-entry body design, flight, and handling.

Current plans of the Section are to feature nine specialist speakers during the year who can give up-to-date state-of-the-art information in various fields to the personnel at AFMTC and other interested parties.

—Robert Eley

Northern California: The March meeting was held at Sabella's in Sunnyvale, Calif. It was especially gratifying that a contingent from the Monterey Section was present at this meeting. The evening featured a talk by **Wallace Davis,** president of Vidya, Inc., on "Research and Development Work at Vidya." In a highly amusing introduction, Davis pointed out the problems that beset an organization in starting a new business. Specifically noted were the matters of finance and security, where it is impossible to get financing without contracts and contracts cannot be obtained because there is no "need to know" for security clearance. He described some of the research projects in fluid mechanics, thermodynamics, and chemical physics of propulsion with which his company is currently engaged.

—H. M. Kindsvater

Sacramento: The Section's first 1960 meeting, held at the Sacramento Inn on February 3, saw the installation of new officers, who are as follows: President, L. J. Bornstein; vice-president, J. J. Peterson; corresponding secretary, D. W. Whittlesay; recording secretary, M. Halebsky; and treasurer, G. F. Peltz. Later in the evening, **Philip H. Brunstetter** gave a stimulating talk on "Leadership Styles and Their Implications to Work Accomplished." Dr. Brunstetter has a Ph.D. in psychology and administration from Columbia Univ., has served as assistant dean of students at the City College of N.Y., and was super-

visor of management development for Republic Aviation before joining Aerojet recently in a similar position.

He discussed the philosophies underlying basic leadership and how these are manifested in practice, and pointed to certain surveys which have shown that: High motivation in science is related to high research performance; a scientist should be able to grow while continuing with research; the participative style of leadership works best; productivity is low if there is very little contact with the boss, even if the subordinate has freedom of action and decision; and the most effective leader is one who employs the participative style and has strong technical competence. During the ensuing question-and-answer period, Aerojet vice-president **C. C. Ross** commented on the general area covered by the talk and stated that how to pick the right people for important jobs is a real problem at Aerojet.

The second 1960 Section meeting, held later in February and open to guests, featured a popular talk by **S. C. Burket**, head of the Solid Rocket Plant's Propellant R&D Laboratory, on "Space, The Future, and Solid Propellants." Dr. Burket explained the technical aspects in nontechnical terms so that they were easily understood. He described grain and motor design, and pointed out that it is desirable to have high-temperature and low-molecular-weight gases as a result of solid-propellant combustion in order to obtain high specific impulse. Two problems cited by Dr. Burket for resolution in the future were: How to stop and start solid-propellant rockets; and how to develop low-burning-rate solid propellants which can burn for a long time at low pressure. These latter would be useful for space vehicles.

—D. W. Whittlesay

S. W. Bradstreet of Armour Research Foundation points out defects in a composite-material rocket nozzle to C. C. Miesse, after addressing the Chicago Section on "Composite Materials for Rockets and Missiles."

Wichita: The first regular meeting of 1960 was held in February at Innes Tea Room. This was a joint meeting in cooperation with local sections of IAS and SAE, and drew a combined attendance of 214 members and guests. Speaker for the evening was **Richard W. Porter** of GE, who gave an interesting talk on recent discoveries in space exploration and a summary of some of the current problems being investigated.

—Roger J. Nyenhuis

STUDENT CHAPTERS

Univ. of Conn.: The Chapter held its March meeting in the campus' Student Union. Guest speaker was **Charles E. Waring,** head of the Dept. of Chemistry at the University, who discussed "Sense and Nonsense in Chemical and Biological Warfare." Dr. Waring presented an interesting and informative clarification of the present-day threat of this method of war. Included was a film, released last month by the government, on a chemical agent that induces fear. The meeting resulted in an increase in membership, and it initiated considerable discussion about chemical and biological warfare.

Also, the Chapter recently elected the following slate of officers for 1960: President, David Gruenig; vice-president, Donald Armentano; treasurer, Robert Gruss; programs committee chairman, Allan Kessler; advisers, Dr. Charles A. Reynolds and Richard Rhodes II.

There will be a trip during spring vacation to Electric Boat Co. in Groton, Conn., to see the work being done there on closed ecological systems.

—David E. Gruenig

CORPORATE MEMBERS

American Bosch Arma Corp. has signed an agreement to purchase Tele-Dynamics, Inc., to be operated as a division of ABA . . . **American Potash & Chemical Corp.**'s expansion program during 1960–62 will run into about $25 million . . . **Atlantic Research Corp.** has installed a $700,000 high-speed Burrough 220 electronic computer system . . . **"The Bendix Corporation,"** as adopted by stockholders, will be the new name of Bendix Aviation Corp., effective June 1 . . . **Boeing's** AeroSpace Div. is centralizing its electronic systems work for Minuteman under a 25,000-sq-ft hangar . . . **Burroughs Corp.** has undertaken a major reorganization. In one of the moves, the Burroughs and ElectroData divisions will be discontinued as organizational units; their marketing activities will be joined in the Equipment and Systems Marketing Div.

Chance Vought has agreed to purchase unissued stock and an 80 percent interest in Information Systems, Inc., Skokie, Illinois firm in the automation field . . . **Douglas** is tripling space allotted for its missile nozzle research and production activities, with more than 100,000 sq ft in reserve. The company also plans an engineering center for its missiles and space systems engineering activities . . . The new $1 million R&D Laboratory at **Electro-Optical Systems, Inc.** doubled the company's physical size to 70,000 sq ft . . . **Food Machinery and Chemical Corp.** has dropped the name

A Solid Meeting

Smiling for the camera are Stanley Burket, on the left, head of the R&D Laboratory at Aerojet-Sacramento, and Laurence Bornstein, right, senior engineer at the Solid Rocket Plant and new ARS Sacramento Section President. They may be happy about solids, which Dr. Burket discussed at a recent Section meeting, or about the Section membership, which is now over the 400 mark. The ladies are the "Mrs."

Westvaco from its divisional and brand identifications. Former Westvaco Divs. will hereafter be known as the Chlor-Alkali and Mineral Products Divs. FMC has entered the expoxy plastics field with development of a series of "unique epoxy resins."

GM recently dedicated its new Advanced Concepts R&D Lab in Los Angeles, a missile and space facility within the AC Spark Plug Div. . . . **Grand Central Rocket Co.** has announced that Lockheed has acquired a 50 percent interest in the firm for cash . . . Name of **Hoffman Electronics Corp.**'s Hoffman Laboratories Div. has been changed to Military Products Div. . . . A new plant to serve East Coast industry with **Linde Co.**'s Flame-Plating process will be built at North Haven, Conn. . . . **Arthur D. Little, Inc.**, announces it is establishing an engineering operation in Santa Monica, Calif.

In a reorganization move at Martin-Baltimore, all engineering other than electronics has been incorporated into a new Weapons System Engineering Div.; and an Electronics Div., with integrated engineering and production facilities, has also been set up . . . **Marquardt** has formed a new Facilities Engineering Div. . . . **McDonnell Aircraft** has ordered a "Hotshot" type wind tunnel from Westinghouse Electric. The company has created the McDonnell Automation Center as a commercial arm offering electronic data processing services . . . **NAA**'s Rocketdyne Div. is taking over the 150,000-sq-ft Atomics International building at Canoga Park where it will set up a research center for new methods of space propulsion . . . **Northrop** has paid cash for American-Standard's Military Products Div., Norwood, Mass., which will now operate as the Precision Products Dept. of the Nortronics Div.

Olin Mathieson Chemical Corp. and Pennsalt Chemical Corp. have jointly formed the Penn-Olin Chemical Co., a subsidiary to produce sodium chlorate and other chlorate compounds . . . **Philco**'s Government and Industrial Group has formed a separate Computer Div. at Willow Grove, Pa. . . . **Raytheon** has signed an agreement for exchange of technical knowhow in the microwave tube field with Compagnie Generale de TSF (CSF) in Paris.

New production and engineering facilities for **Rocket Power/Talco,** a division of The Gabriel Co., were recently dedicated at Mesa, Arizona. The complex includes a 50,000-sq-ft solid-propellant production and loading center to produce over 100,000 lb of solid propellant per month . . . **Servomechanisms, Inc.**, has established a separate research division at its Santa Barbara facility . . . **Solar Aircraft** has been acquired by International Harvester via exchange of 1 share of IH for $2^1/_4$ shares of Solar . . . New engineering center being built at Euclid, Ohio, for **Thompson Ramo Wooldridge**'s Tapco Group will be named in honor of TRW's vice-president Arch T. Colwell, who has headed engineering R&D activities there for 30 years.

United Aircraft has recently acquired exclusive North American rights to a new electron beam process developed by Carl Zeiss Foundation of West Germany for machining or welding the hardest materials, and has set up Corpuscular, A.G., a Swiss company, to market the machines overseas. The Pratt & Whitney Aircraft Div. has entered into a joint R&D program with Leesona Corp. covering the field of fuel cells . . . **United Research Corp. of Menlo Park** has changed its name to United Technology Corp. . . . **Wyle Laboratories** has acquired Parameters, Inc., New Hyde Park, N.Y., to be known hereafter as Wyle-Parameters, engaged in testing of missile and aircraft components. ♦♦

IAF Congress Registration Forms Available From ARS Headquarters in New York

Registration forms for the 11th International Astronautical Congress, to be held at the Royal Technical Institute in Stockholm, Sweden, August 15–20, are now available from ARS Headquarters in New York.

The forms may be obtained by writing to Rod Hohl, Meetings Manager, American Rocket Society, 500 Fifth Avenue, New York 36, N.Y. The Swedish Interplanetary Society, host for the Congress, has indicated that it must receive the filled-in forms by May 15 in order to make necessary arrangements for blocking off sufficient hotel rooms for registrants.

Plans for ARS charter flights from Los Angeles and New York to Stockholm have been canceled due to a recently enacted Civil Aeronautics Board regulation prohibiting organizations with more than 5000 members from making a nationwide solicitation for charter plane passengers. All ARS members intending to attend the Congress are, therefore, asked to make their own travel arrangements, but to use the IAF Congress registration form for hotel reservations and as a notice of official intent to attend the Congress.

Tentative plans for the Congress program include sessions on the following topics:

1. Planetary Atmosphere Environments; 2. Interplanetary Space; 3. Space Medicine and Biology; 4. Trajectories; 5. Navigation, Guidance and Control, Space Communication; 6. Propulsion; 7. Vehicles; 8. Space Probes, Satellites, High-Altitude Rockets (descriptions and presentation of results); and 9. Economic Factors.

LA Meeting Program

(CONTINUED FROM PAGE 50)

Tuesday, May 10

Tour B **1:30 p.m.**

Marineland of the Pacific

Buses will travel directly to Marineland. Visit includes outdoor show featuring trained whales and porpoises, seal show, and observation of all the various undersea life of the Pacific. Buses will return to the hotel by 5:30 p.m. (approx.).

Cost: $2.75

Wednesday, May 11

Tour C (Ladies Only) **2:00 p.m.**

Hollywood

Universal International Studio, Griffith Park, Walt Disney Studio, Columbia Studios Ranch, Hollywood Bowl, etc., 3 hours.

Cost: $4.75

Thursday, May 12

Tour D **9:00 a.m.**

Disneyland

Buses will travel directly to world famous Disneyland. Visit may include all the wonderful rides available, such as the Jungle River Boat, the Submarine Nautilus, the Steamboat Mark Twain, etc. Return buses will leave Disneyland promptly at 2:30 p.m.

Cost: $3.25

6:00 p.m.

Reception and Banquet—Poolside and Embassy Room

Ambassador Hotel

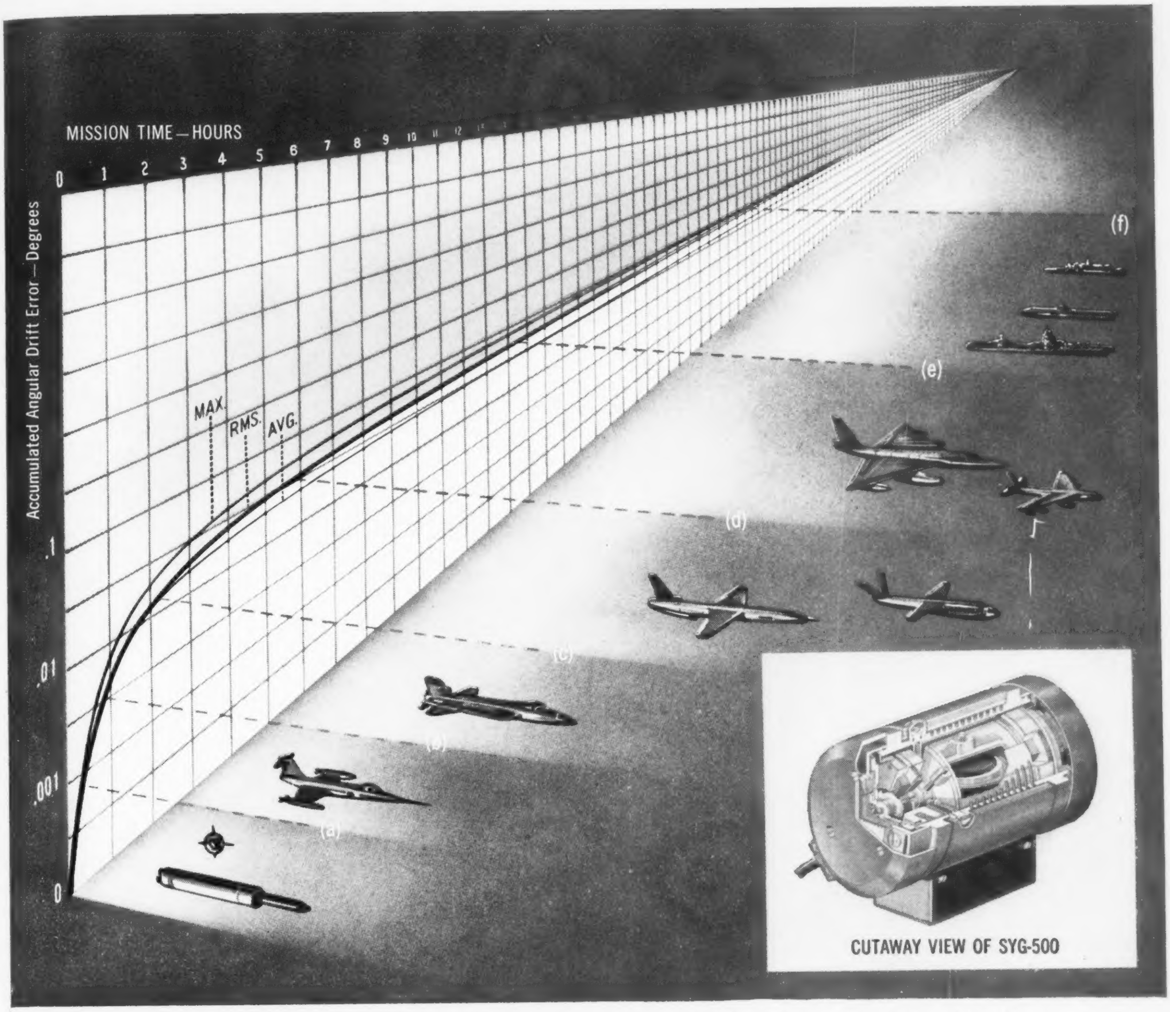
Ticket: $9.50

Friday, May 13

Suggested shopping day. Members of the Hostess Committee from Los Angles will be available to offer assistance and guidance. Individual tours to other points of interest in and about Los Angeles can also be arranged.

Science Encyclopedia

One of the largest technical publications ever undertaken in the English language, an encyclopedia of science and technology in preparation for over four years, will be published in 15 large volumes next fall by McGraw-Hill.



PERFORMANCE ACCURACY OF SYG-500 GYRO PLOTTED AGAINST MISSION TIME: a) Satellites and Ballistic Missiles, Ascent Phase; b) Tactical Aircraft (Short Range); c) Hypersonic Glide Vehicles; d) Cruise Missiles; e) Strategic Aircraft (Long Range); f) Marine Craft.

Sperry SYG-500 FLOATED INTEGRATING GYRO offers full-mission accuracy . . . flight-proven reliability

- **New non-freezing Gyrolube™ flotation fluid**
- **Isoelastic gimbaling**
- **Long-term drift stability**
- **New long-life low-wear spin wheel bearings**

As requirements for inertial guidance systems continue to stiffen, Sperry answers with the SYG-500 Floated Integrating Gyro—available in production quantities for use in a wide range of ballistic missile, space vehicle, aircraft and marine applications.

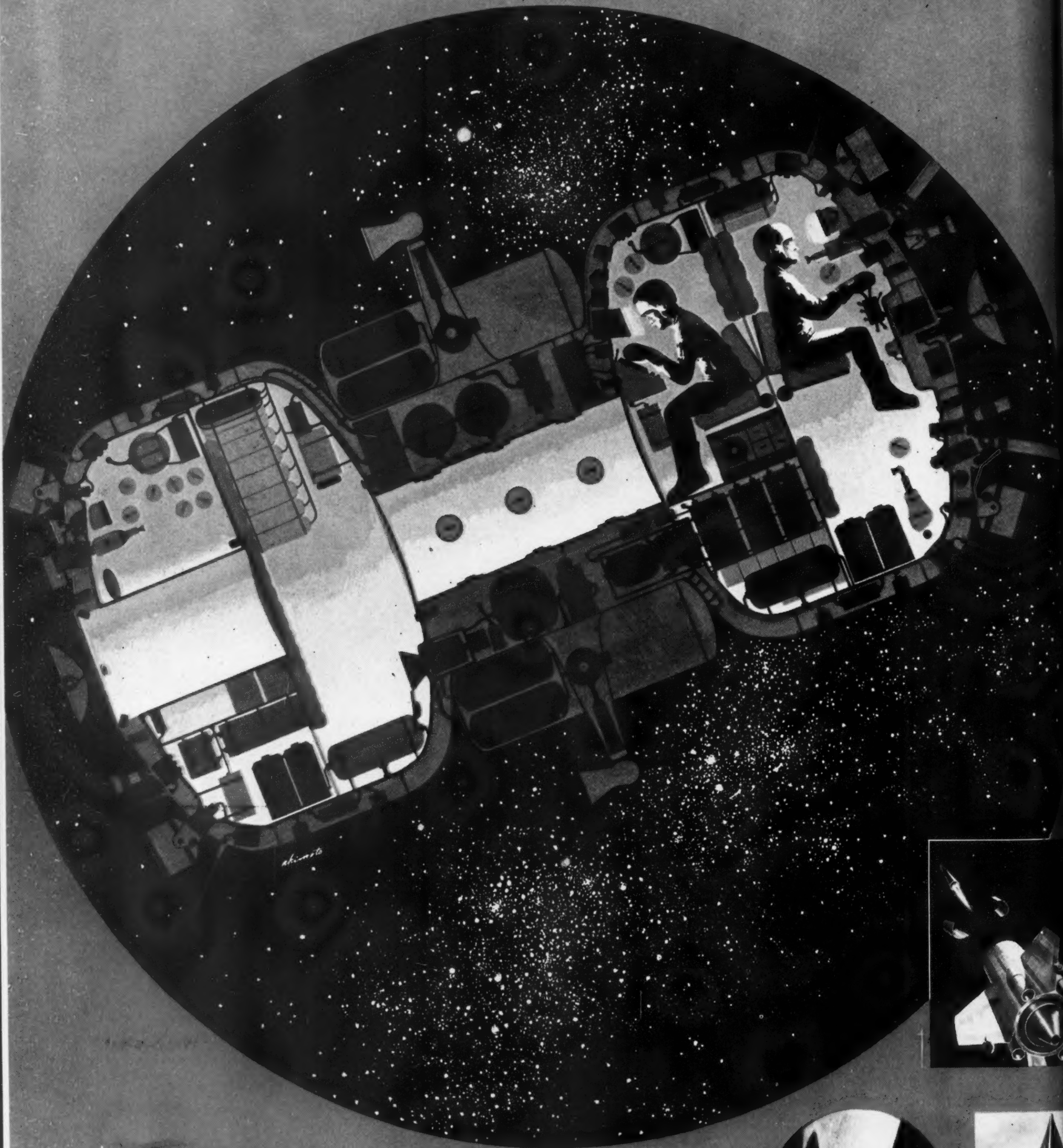
The SYG-500 is the result of the most thorough study, analysis, evaluation, lab- and flight-testing of any floated gyro in production today. It is rugged, with full accuracy even after exposure to acceleration, vibration and impact shock (MIL-E 5272B). It is non-freezing; a new flotation fluid, Sperry Gyrolube, permitting unlimited storage between –65°F. and +180°F. without impairment of accuracy. Thermal equilibrium is rapidly attained as a result of advanced insulation techniques. New low-wear spin wheel bearings contribute to a life in excess of 3500 hours.

The Sperry SYG-500 is *fully flight-proven* on high performance aircraft. Write for detailed specifications and supporting data.

SPERRY 50 YEARS 1910 1960

AIR ARMAMENT DIVISION, *SPERRY GYROSCOPE COMPANY • DIVISION OF SPERRY RAND CORPORATION, GREAT NECK, N. Y.*

EXPANDING THE FRONTIERS OF SPACE TECHNOLOGY



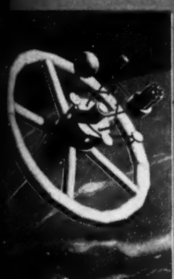
THE ASTROTUG

Tugboat for Space: Spaceborne scientific laboratories and platforms for further exploration into space are an accepted concept based on established engineering techniques. Components would be fired as individual units into space, on precalculated orbits, and there assembled. To solve the major problems of how men are to live and work in space during the assembly process, Lockheed has prepared a detailed engineering design of an astrotug—a manned vehicle housing a crew of two or three. Missile-launched, the astrotug will be capable of supporting its crew for a number of days in an environment of suitable atmosphere, artificial gravity, and with provisions for exercise, relaxation, bathing facilities, medical care, illumination and adequate food and water.

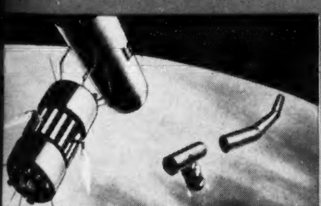
The Lockheed astrotug is a completely independent working vehicle. Personnel need not leave it in space suits in order to work on the project of assembling the space station components. As shown in the diagram, the tug consists of two double-walled pressure vessels approximately 20 feet long overall and 9 feet in inside diameter. Swivelling rocket nozzles are arranged for maneuvering. On the forward end, extending out are four mechanical manipulator arms with interchangeable "hands" for such specialized functions as gripping, welding, hammering, cutting, running screws, etc. "Hands" can be changed by remote control from inside. Viewing ports provide uninterrupted observation. Radar antennas, searchlights, and other equipment necessary to the tug's work are mounted externally. Main controls and instruments including radar, radio, infrared, computers and navigation consoles are duplicated in each of the two major compartments as a safety measure.

Men working in single units afloat in space suits would have little applicable force and could work for very limited periods of time. With the Lockheed astrotug, personnel could carry on the work in relative safety and comfort with maximum efficiency. A special reentry vehicle, separate from the astrotug, has been conceived for ferrying to and from earth. Tugs themselves would remain floating in orbit indefinitely, being reprovisioned and refurbished as fresh crews arrive in relief.

Space vehicle development is typical of Lockheed Missiles and Space Division's broad diversification. The Division possesses complete capability in more than 40 areas of science and technology—from concept to operation. Its programs provide a fascinating challenge to creative engineers and scientists. They include: celestial mechanics; computer research and development; electromagnetic wave propagation and radiation; electronics; the flight sciences; human engineering; magnetohydrodynamics; man in space; materials and processes; applied mathematics; oceanography; operations research and analysis; ionic, nuclear and plasma propulsion and exotic fuels; sonics; space communications; space medicine; space navigation; and space physics.



Engineers and Scientists: Such programs reach far into the future and deal with unknown and stimulating environments. It is a rewarding future with a company that has an outstanding record of progress and achievement. If you are experienced in any of the above areas, or in related work, we invite your inquiry. Please write: Research and Development Staff, Dept. E-14, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense clearance required.



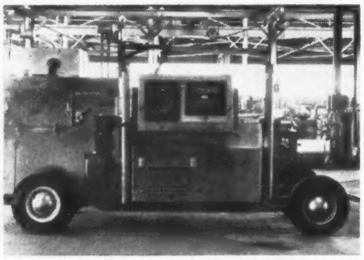
Lockheed

MISSILES AND SPACE DIVISION

Systems Manager for the Navy POLARIS FBM; the Air Force AGENA Satellite in the DISCOVERER, MIDAS and SAMOS Programs; Air Force X-7; and Army KINGFISHER.

SUNNYVALE, PALO ALTO, VAN NUYS, SANTA CRUZ, SANTA MARIA, CALIFORNIA
CAPE CANAVERAL, FLORIDA • ALAMOGORDO, NEW MEXICO • HAWAII

Mobile Unit Conditions Missile Components



Recently delivered to Army missile ranges, this mobile unit, produced by Cook Electric's Nucledyne Div., will temperature-condition missile components in preflight preparation. Its environmental chamber will hold a temperature within plus or minus 2 F between −100 and 200 F.

Impact of the Space Age

On May 7, an education symposium on "The Creative Challenge to Man in the Space Age" takes place at the Univ. of Minnesota under the sponsorship of the University's College of Education, the Minnesota Wing of the Air Force Assn., and the Civil Air Patrol. The purpose of the symposium is to raise questions and suggest possible results of the impact of the Space Age on American life. It will feature such distinguished speakers as Margaret Mead, E. W. Rawlings, Robert F. McDermott, Paul W. Cherington, and E. Paul Torrance.

NASA Lunar Conference

(CONTINUED FROM PAGE 45)

originate in the asteroidal belt, but seem to eliminate that region as the source of the stones. It appears that the stones must be moving in orbits close to that of the earth, and Urey suggests that some of them may in fact be bodies which have been removed from the moon by collisions of iron meteorites with that object, or by collisions with the residues of comet heads. If a stone lies a meter or more beneath the surface of the moon, it will be protected from cosmic radiation by the overlying rock until it is ejected into an orbit around the sun by a collision of a meteorite with the moon's surface. A difficulty with this picture is presented by the fact that among the stone meteorites there is one, Norton County, whose cosmic-ray age is several hundred million years. However, Norton County may be only an object that was lying on the surface of the moon and was therefore subject to cosmic-ray bombardment before it was removed by collision.

Urey emphasizes that whether or not the chondrites come from the moon, the stones and the irons have had a very different history if the cosmic-ray data are reliable.

In the ensuing discussion, Harry Hess of Princeton Univ. commented on the difficulties in supposing that the meteorites come from the interior of any planet. He remarked that materials which come up from the depths of the earth, where they have been under substantial pressure, reduce themselves to an exceedingly friable material as soon as the pressure is released. He thus supported Urey's argument that, since the chondrites are not friable, they must come somehow not from the interior but from the surface of a planet.

Argon-Potassium Ages

A very different point of view on the origin of stone meteorites was expressed by E. Anders of the Univ. of Chicago. Anders based his remarks on measurements of the argon-potassium ages of the meteorites; K^{40} undergoes a transformation to A^{40} by electron capture plus gamma emission. This process is the only source of A^{40} in the meteorite. A measurement of the relative amounts of argon and potassium in a given rock is therefore a direct measure of its age. A similar but independent determination of the age may be obtained from a measurement of the relative concentrations of strontium and rubidium, since these two elements are related by a beta decay scheme. We expect the argon-potassium age to be lower than the rubidium-strontium age because some loss of argon can be expected by diffusion to the surface of the meteorite. Anders has found that in actuality the two ages are closely the same. He estimates that no more than 30 percent of the argon has been lost by diffusion to the surface during the 4 billion years of the meteorites' lifetime. Since the diffusion rate depends on temperature, he derives from the argon loss an estimate for the mean temperature of the meteorite during its lifetime. A quantitative analysis based on measurements of the diffusion constant for argon in rocks indicates that the temperatures of the meteorites cannot have been more than 200 K during most of their lifetimes. If this temperature is considered to be produced by the equilibrium between absorption and re-radiation of the sun's energy, it corresponds to a distance from the sun of about 1.5 astronomical units (A.U.). That distance is approximately the radius of the asteroidal belt, and Anders' reasoning therefore supports the hypothesis that the stone meteorites originate in the asteroidal belt and not in orbits close to that of the earth.

The argument can be extended to obtain an upper limit to the size of the bodies which formed the parents of the meteorites. The temperature of a meteorite must be appreciably increased by radioactive heating if it is contained in a parent object of sufficiently great size. If an upper limit can be set on the temperature increase produced by radioactive heating, a maximum will also be obtained for the size of the parent object. Now, the meteorites or their parent bodies might have originated as far as 5 A.U. from the sun, but no further, because at greater distances they would be swept up rather quickly by the planet Jupiter. At a distance of 5 A.U. the temperature at equilibrium with the sun's radiation will be about 110 K. A temperature of this magnitude would be produced in the interior of an object approximately 250 km in diam, and according to Anders this size is therefore the maximum permissible for the object from which the meteorites are formed.

Urey has noted that this conclusion on the size of the parent object to the meteorites would appear to be inconsistent with the presence of diamonds in these bodies. As far as is now known, the manufacture of diamonds requires extremely high pressures, such as are only to be found in the interior of an object the size of the moon or larger.

Thus there is a decided difference of opinion regarding the origin of the stones, although there appears to be general agreement that the iron meteorites originate in the asteroidal belt.

The Tektites

Another group of objects and their possible lunar origin were the subject of a very lively debate in the conference. These are the tektites, a glassy rock which is picked up in great numbers in Australia and elsewhere around the world. It is not clear that the tektites come from outer space, and it is in fact the general opinion among geologists that they are a form of terrestrial rock which has been subjected to a special processing of unknown character. However, several students of the subject, including Suess, Ninger, Fenner, and others, believe that these objects are of extraterrestrial origin. The arguments for their views were presented at the conference by J. A. O'Keefe of NASA.

The essence of these ideas is that the tektites represent ablation products from a natural satellite of the earth, i.e., a body of meteoritic size which

is moving in the earth's gravitational field. Such objects may be subjected to extended heating as they enter the upper atmosphere, if they approach in an almost circular orbit. O'Keefe suggests that it is possible to account for the sizes and forms of the tektites on the assumption that they are drops which were detached from the larger bodies as they entered the atmosphere along grazing paths. Some considerations adduced in support of this theory by O'Keefe are the following.

First, the chemical composition is not close to that of other rocks in the neighborhood of points where they are picked up; furthermore, they have a characteristic and uniform composition, although they are found in a belt covering large areas over which the composition of the indigenous rocks varies substantially. Second, they have markings on them which show signs of flight through the atmosphere of the earth, i.e., lines of flow such as would be produced in the melting and ablation of a rock as it entered the atmosphere of the earth. Third, they have only 20 to 200 parts per million of water, and are drier than almost any terrestrial rock. Fourth, they have at most 1 part per million of gaseous material, and this exceptional freedom from volatiles can only be understood if it is assumed that the tektites have been subjected to high temperatures for extended periods, as in the course of atmospheric entry at a small angle.

As the source of the natural satellite, O'Keefe, following Nininger, proposes the moon. He points out that in the impact of meteorities with the moon's surface, most of the fragments ejected by the collision will go into the solar system, but some will be captured by the moon and the earth into natural satellite orbits initially resembling that of Lunik III. Those which come near the earth will be subjected to an atmospheric drag which decreases the eccentricity of their orbits until they achieve a circle and enter the atmosphere at a small angle. According to the calculations of E. Opik, this process must take several thousands of years. In the final stages of atmospheric entry the tektites drip from the body of the natural satellite as its surface melts.

Urey attacked this explanation on the ground that Aluminum 26, which is formed by cosmic-ray bombardment and is found in meteorites, is not found in the tektites, nor is Neon 21. He also raised the objection that, while many of the tektites may come in on grazing orbits, a smaller but still comparable number enter directly and produce ordinary meteorites with the composition of tektites, and these have not been formed, with the possible exception of one object. A. R. Hibbs drew attention to the fact that in all of the orbits which he had so far calculated for lunar probes, it has turned out that the probe falls to the ground within a few years of being put into orbit. Hibbs suggests that the length of life in the earth-moon system would be rather short and, moreover, that the body would end its life not by spiralling into the earth, as observed in the case of Sputnik II and suggested by O'Keefe, but, on the contrary, would suffer larger perturbations of the perigee which would cause it to fall directly to the ground.

Lunar Seismology

Seismometers for the detection of moon quakes are being developed under the direction of Maurice Ewing at Columbia Univ. and Frank Press at the California Institute of Technology, as part of the NASA lunar exploration program. A rugged construction appears to be feasible for these lunar seismometers, and they may be placed in one of the first instrumented stations to be landed on the moon. Since the level of natural seismic activity on the moon may be low, it is hoped that large meteorite falls will occur with sufficient frequency so that they may be picked up by the seismometers during the month or so in which their power supply can be expected to function. An examination of the records of meteorite falls on earth has therefore been undertaken by Harrison Brown of CalTech in an effort to predict the probability of detectable lunar impacts. His research parallels an earlier investigation by Opik in the same area. The results of Brown's study, as reported at the conference, indicate that one impact with a magnitude of a ton may be expected on the moon every 10 years. A fall of this magnitude should be detectable by the seismometer at any point on the moon's surface. There is presumably a higher frequency of smaller falls which would be detectable if they occurred in the close neighborhood of the seismometer. The uncertainty in these estimates is considered by Brown to be very great, although taken at face value they appear to indicate unfavorable conditions for this particular mode of operation of the lunar seismometer.

Statistics of Meteor Falls

The statistics assembled by Brown have their own interest apart from their application to the lunar exploration program. His records indicate an increase in the frequency of meteorite finds with time, presumably due to the recent increase in world population. Between 1800 and 1940 the records show an average of 7 falls per year, or 170 falls per year over the entire surface of the earth, of which 6 percent are iron meteorites and the remainder are stones. Of the stones, 90 percent are chondrites and 10 percent are achondrite.

A highly uncertain extrapolation of the frequency curve to very large meteors indicates that impacts such as that which produced the Arizona crater will occur once every few thousand years. Over an interval of some hundreds of millions of years, fantastic collisions can be expected, such as could in fact be expected to bring about extinction of life on the earth.

Changes in the Radius of the Moon

The conference continued with a report by MacDonald on the thermal history of the moon. According to MacDonald the absence of horizontal displacements on the surface of the moon indicates that the radius did not change by a substantial amount over the last several aeons. There are cracks on the moon, such as those around Copernicus, which indicate that the moon has opened up or increased in radius slightly in an early stage. Over the last two aeons, however, the radius cannot have changed appreciably.

The absence of appreciable change in the radius of the moon is now used as the basis for the following calculation. The moon is assumed to be a spherical distribution of matter containing radioactive elements whose decay heats up the interior. The heat passes to the surface of the moon, and produces an expansion of its radius at a rate determined by the average value of the thermal expansion coefficient for lunar matter.

From the theoretical result for the rate of change of radius, the conditions are determined under which the moon's radius can remain constant in time. On this basis, MacDonald has calculated several thermal histories for the moon. In the first calculation the initial temperature is assumed to be zero C, corresponding to a cold moon formation. In other calculations the initial temperature is given values ranging up to 1200 C. The results for change of radius with time do not depend essentially on the initial temperature assumed, and in all models it is found that the radius increases rapidly over the first 1 $^1/_2$ aeons, primarily because the initial rate of heating by radioactive decay is very large. After one or two aeons the radius levels off and begins to decrease, but at an extremely small rate. The calculated rate of decrease in this period is approximately 500 meters per aeon.

For an initially cold moon, the peak

temperature in the model is 1700 C; it is 2100 C for a moon with an initial temperature of 600 C. At a peak temperature of 2100 C, any iron which might be present would be melted, and this is true throughout most of the interior of the moon. At this temperature silicates might or might not melt.

The next point considered by MacDonald is the level of lunar seismicity. Internal heating produces differences between the radial and the tangential stresses; and when these stresses exceed the critical value for typical silicate materials, the structure fails either by rupture or by flow, and moon quakes result. MacDonald's calculations on the thermal history of the moon are used to determine the rate of release of distortional energy. He finds that the seismicity is comparable to that observed on earth. He also finds, however, that the failures occur at relatively deep levels, some 600 km below the surface, and may therefore be difficult to detect.

In the ensuing discussion, there was considerable controversy over the type of rock to be assumed for lunar matter, since on earth the various forms of rock vary substantially in percentages of the radioactive elements, and these elements play an essential role in MacDonald's calculations.

James R. Arnold from the Univ. of California took a position above the battle in his presentation of preliminary results of a project to measure lunar radioactivity, carried out in collaboration with Anderson and Van Dilla at Los Alamos. He was delighted, as an experimentalist, to find that the composition of the moon was a matter so much in debate, since the most important experiments are obviously those which cast light on this controversial question. He described the instruments which are being built for the measurement of lunar radioactivity from an orbiting satellite. With these, he hopes to measure in surprising detail the chemical composition of the moon, using the spectrum of gamma rays emitted from the surface of the moon as his tool for the analysis.

The gamma activity will be produced in part by the decays of potassium, uranium, and thorium. Since the various substances which have been proposed for the composition of lunar matter differ in relative percentages of these elements, the gamma-ray experiment will give direct information on the composition of the crust. In particular, it will distinguish in a very clear manner between the tektites and the chondrites.

Nuclear reactions produced by cosmic rays will lead to the production of neutron capture gammas, and it appears that under favorable circumstances the analysis of these gammas may permit the detection of as many as twelve elements in the lunar crust, in addition to the naturally radioactive elements.

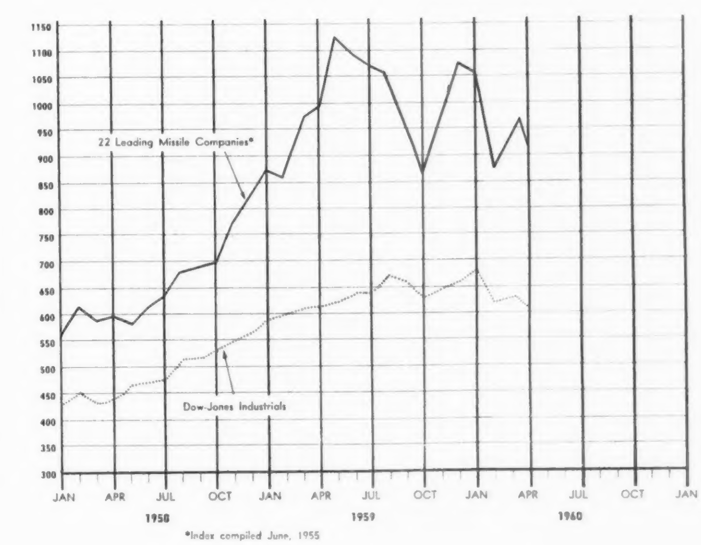
The Lunar Surface

Thomas Gold of Cornell Univ. rose, the last speaker, to comment on the implications of the remarkable smoothness of the lunar surface. Radar evidence indicates clearly that the moon is smooth on a scale of about 10 cm. The question Gold now raises is, What has covered over the many small craters which should have been produced by the bombardment of meteorites of moderate size? Such craters should pit the surface of the moon, and yet we know that on a scale of 10 cm the surface is smooth. Gold remarks that something must have occurred, either that the small impacts did not happen, and that seems unlikely, or some mechanism smoothed them over.

Gold considers the possible mechanisms for the transport of fine particles across the lunar surface, so as to collect these particles in all depressions of the terrain. He suggests a process of electrostatic diffusion, produced by chance accumulation of charges on contiguous particles in the dust layer. The charges are assumed to result from the bombardment of the surface by streams of solar protons. Under the influence of forces of electrostatic repulsion, the particles hop around the surface; if they are on a slope they will walk downhill; if a pit or cavity is present they will fill it in.

In the discussion of Gold's dust hypothesis, Urey commented that G. K. Gilbert has supposed the great dark areas in the moon to be due to a flow of lava produced in the collision of great meteorites with the moon; but it was possible also that they might be the deposition of a great cloud of dust which rose from the surface and fell back near the collision center. It seemed to be the consensus in the conference that great meteorite impacts will in fact produce much more dust and rubble than lava, and that at least some of the maria may be such beds of dust and broken rock. ♦♦

Missile market



	April 1960	March 1960	% Change	April 1959	% Change
Dow-Jones Industrials	617	630	−2.1	602	+2.5
Missile Index	924	993	−7.0	997	−7.0

X-15 Operations

(CONTINUED FROM PAGE 43)

the most suitable approach for the X-15's relatively short flight duration, and it was selected for the primary cockpit presentation and data recording.

The X-15 inertial flight-data system was developed and built by Sperry Gyroscope Co. It is composed of a stabilizer and computer in the X-15 and an inflight control panel in the B-52. The B-52 controls set initial conditions and monitor the stabilization and alignment of the inertial platform prior to launch.

The stabilizer consists of three linear accelerometers and three integrating gyros mounted on a platform which is kept perpendicular to the local gravity vertical under all possible conditions of attitude and acceleration by means of four separate gimbals. The servoamplifiers for each axis are transistorized and mount directly on the gimbal being driven, thus minimizing slip-ring requirements. The gimbal itself is used as a heat sink for power transistors.

This design approach, which essentially eliminates gearing on the gimbal axes, enhances the performance of the platform under vibration. The linear accelerometers have a threshold within 10^{-5} g and an accuracy over life and environment without recalibration of the order of 10^{-4} g. Power supplies and accessories are contained within the stabilizer housing. The case design, in addition, serves as a heat exchanger between the internal circulating air and the external cooling gas.

The computer performs all the computations necessary to derive altitude, velocity, and position data in a suitable form. It includes the following functions:

1. Doppler inertial mixing.
2. Gyro-drift storage.
3. Acceleration-to-velocity integration.
4. Velocity-to-position integration.
5. Earth-rate computations.
6. Acceleration corrections (Coriolis and centripetal) due to kinetic velocities.
7. Acceleration corrections due to changes in mass attraction.

The computer is capable of operating over a 720- x 240-mile area. The ability to superimpose this space over the geographically known High Range for every flight considerably simplifies the computer requirements. The light weight and high accuracy of the computer are additionally enhanced by the unit's direct-current analog computing concept. All required power supplies are packaged within the unit.

The initial conditions are inserted from the control unit in the B-52. Along-range and cross-range-velocity components are developed from an AN/APN-81 Doppler radar, and the platform is aligned from an N-1 compass system. The vertical-velocity component is derived from a barometric rate-of-climb sensor. Initial position and altitude are inserted manually.

Alternate methods of flight-condition determination are available to the pilot in the event of failure of the all-attitude flight system. Attitudes, of course, may be observed visually. A visual re-entry requires some change in technique from standard, but does appear feasible. Airspeed and altitude are presented on pressure-sensing instruments in the lower-performance flight regimes. Finally, radar data, including altitude and trajectory or vertical velocity as derived from the velocity computer, can be transmitted verbally from the High Range stations. Data-transmission equipment is utilized to transmit radar information between stations in terms of Cartesian coordinates in binary coded form, which, when converted to polar coordinates, will automatically direct the next radar on target. The radar information is simultaneously recorded and plotted at all three stations.

Radar Contact Maximized

A beacon transponder on the X-15 responds to coded interrogations, maximizing radar-contact probability and minimizing interference from other installations. Azimuth, elevation, and range are recorded at the radar station by means of encoders attached directly to the elevation and azimuth shafts and range potentiometer. The encoder output, in digital form, is recorded at a 10-sample-per-sec rate on an Ampex FR-114 magnetic tape recorder and constitutes the primary precise information obtained from the radar system.

Engine, propellant, hydraulic, and electrical and other aircraft systems are monitored by the pilot primarily with cockpit indicators. A complementary system uses a standard 90 x 10 pulse-duration-modulation telemetry system with a capacity of up to 90 channels of information. Critical system parameters are transmitted to the ground range in real time. Each of the three High Range stations can present all of the transmitted quantities in vertical-bar-graph form on oscilloscopes. Forty selected parameters can be presented on calibrated meters for more accurate assessment

by engineers. Real-time strip-chart recording is available directly at the telemetry stations for as many as 24 channels of information.

All telemetry information is tape-recorded directly from the receiver in PDM form on an Ampex FR-114 magnetic tape recorder. Data can be reduced by replaying the tape directly through the receiving station immediately after flight and recording outputs as time-history data on strip-chart recorders. The magnetic-tape data can also be reduced automatically through the use of the Air Force Flight Test Center "Project Datum." This system will accept a variety of input data tapes and generate output tapes compatible with IBM 704 or other computers for automatic processing.

The servodriven helical telemetry antennae are normally controlled automatically by synchro data from the tracking radar.

Air-to-ground communication is primarily by UHF units designed and constructed specifically for the X-15 by Collins Radio Co. The system is composed of a main transmitter-receiver which provides amplitude-modulated radio-telephone communications on any 20 of 1750 channels in the 225.0 to 399.9 mc band. A separate guard receiver continuously monitors a frequency which provides antenna switching for space diversity. An auxiliary receiver operates on any 20 of 200 channels in the 265.0 to 284.9 mc band.

Ground-communication equipment is standard military UHF (GRC-27). High Range includes a network that insures positive contact between every ground station and any aircraft flying over the range. Each of the three stations contains two transmitters and receivers (primary and standby) and a special communications amplifier and switching unit. The keying of any transmitter causes, by means of land-line connections, the keying of transmitters at the other two stations. The same output is thus transmitted from all stations simultaneously. Receivers similarly place their inputs on the land line such that simultaneous reception at all stations is assured. Each station's transmitter frequency differs slightly from the others to prevent an undesirable audio-beat frequency. Any audible frequencies produced as a result of these offsets are eliminated by the audio-frequency response of the airborne receivers.

An HF communications net is used by the rescue and support aircraft for air-to-air and air-to-ground communication. An additional rangewide intercommunication system is installed for administrative-control purposes.

Navigation in the X-15 is primarily visual. Each X-15 pilot has been flying over the High Range repeatedly for several years during its construction and checkout, and has become intimately familiar with its geography and topography. Navigation augmentation is provided by an automatic direction-finding feature incorporated within the airborne communications equipment. Both the main auxiliary X-15 radio receivers are capable of receiving RF signals from an X-15-mounted ADF antenna, amplifying and demodulating them, and delivering the resulting low-frequency-modulation components to the direction finder and amplifier equipment.

Emergency Information

Secondary emergency-navigation information can be given to the X-15 pilot by the radar space-positioning network. Electronic Associates Type 205J plotting boards are installed at each station for monitoring trajectory data. Each local plotting board has a selectable input either local or incoming radar data from a remote station (parallax corrected) to be plotted. The master station includes an additional plotting board which produces a complete plot of the research flight by sequential acceptance of data from the various tracking radars.

Also, for any combination of speed and altitude, plotting-board overlays are available that show a plan form of the gliding capability of the X-15 together with some indication of the technique required to achieve any desired landing area within the plan-form area. This information is expected to be invaluable in the event of an engine burnout or other deviation from the planned trajectory which would require a landing at one of the several up-range, emergency dry-lake sites. Other useful services normally provided by this facility include B-52 course alignment prior to launch and vectoring information for escort aircraft rendezvous.

We can see in the X-15 program certain truisms for advanced flight. An automated system is improved by minimizing deviations from its predicted norm. A manned system, conversely, thrives on its flexibility. The pilot is pleased most when he is presented the greatest number of alternatives with the fewest number of switches.

The X-15 operation illustrates, in many cases, the selection of alternative methods rather than redundant systems. Failure of particular components will not necessarily cause flight failure or compromise primary research objectives. This philosophy is expected to show substantial profit when the research results are tallied. ♦♦

People in the news

APPOINTMENTS

Howard S. Seifert, national ARS president, has been named professor of aeronautical engineering for propulsion at Stanford Univ. and a member of the research staff of United Technology Corp. He was formerly with Space Technology Laboratories.

Noah S. Davis Jr., former ARS president, has joined the Advanced Design Section of Rocketdyne as a propulsive specialist. He was formerly director of the Special Projects Laboratory of Food Machinery and Chemical Corp.

R. B. Canright has been named Saturn program manager for NASA. An ARS national board member, he was formerly chief of the research section, Missile & Space Systems Div., Douglas Aircraft Co. **Landis S. Gephart,** former chief of ARPA's Exploratory Research and Reliability Branch, has been appointed director of NASA's new Reliability and Systems Analysis Office.

Col. George M. Knauf, staff surgeon for AFMTC, has been appointed bioastronautic assistant for the Armed Services Medical Support for the man-in-space program.

Howard A. Wilcox, formerly DOD deputy director of defense research and engineering, has been appointed director of research and engineering in GM's Defense Systems Div. **Moreton Price** becomes director of sales for the division.

Brig. Gen. John A. Barclay, ABMA commander and AOMC acting deputy commanding general, has been nominated by President Eisenhower for promotion to major general. Also at ABMA, **Jerry C. McCall** has been named assistant to Wernher von Braun, director of Development Operations Div.

Col. Richard C. Gibson has been assigned to the Air Force Academy as professor and head of the Dept. of Astronautics. He previously served as director of the Experimental Vehicles and Instrumentation Div., ARDC, Andrews AFB, Md.

Lewis M. Branscomb has been named chief of National Bureau of Standards' new Atomic Physics Div., an offshoot of the Atomic and Radiation Physics Div.

David S. Lewis has been named senior vice-president, operations, McDonnell Aircraft.

T. F. Dixon, Rocketdyne director of research and engineering, has been made chairman of an ad hoc group charged with recommending to the Dept. of Defense an R&D program of advanced rocket propulsion systems. In a reorganization of its research subdivision, Rocketdyne has promoted **Jack Silverman, L. C. Struckenbruck, R. S. Levine,** and **S. P. Greenfield,** respectively, to head the following sections: Chemistry; Solid Propulsion; Physical Processes; and Liquid Propulsion.

Within the Chemistry Section, **K. H. Mueller** will head the Experimental Chemistry Group; in the Solid Propulsion Section, **Charles Bernstein** will head the Propellants and Polymers Group, **R. D. Sheeline,** the Solid Propellant Application Group, and **C. H. Martinez,** the Special Projects Group; in the Physical Processes Section, **J. E. Witherspoon** will head the Physics and Mathematics Group and **R. B. Lawhead,** the Process Dynamics Group; and in the Liquid Propulsion Section, **G. S. Gill** will head the Liquid Engine Appplications Group and **J. V. Hobbs,** the Research Instrumentation Group.

At Aerojet-General, **John V. Atanasoff** has been appointed vice-president of the Atlantic Div., and **Capt. Sheldon Brown** (USN-Ret.) becomes assistant manager there. **W. J. Wiley** has been upped to manager, missile manufacturing, of the company's Downey plant. **Comdr. Eric G. Newberg Jr.** is the new resident representative for the Bureau of Naval Weapons at Aerojet's Sacramento plants.

Three new managers have been appointed in GE's Missile and Space Vehicle Dept.: **Edward A. Miller,** in charge of the Discoverer Program; **Solomon Charp,** Navigation and Control Electronic Equipment; and **William J. Conner Jr.,** Defense and Business Planning.

Richard B. Uhle has been named executive assistant to the vice-president and general manager of defense operations at Avco's Crosley Div.

At United Aircraft Corp.'s Norden Div., **Carl F. Schaefer** and **Ernest J. Greenwood** have been named engineering and operations managers, respectively. At the Hamilton Standard Div., **Rex E. Moule** has been appointed chief of basic design.

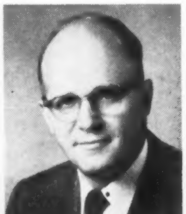
Arthur Bramley has joined the electronics section of Republic Aviation's scientific research staff.

Royal V. Keeran has been appointed technical director of Marquardt's Pomona Div., and **John A. Swint,** director of operations, Ogden Div.

Richard W. Eppley has joined the Astro Systems and Research Laboratories of Northrop's Norair Div.

Patrick J. Mallon has been made director of reliability and quality, general office, Hughes Aircraft Co. In the company's Ground Systems Group, **Nicholas A. Begovich** has been appointed assistant manager; **Robert M. Snyder** becomes manager of the Radar Systems Dept. of the radar laboratory; **Arnold M. Small,** manager of the product effectiveness laboratory; and **Lester V. S. Sanson,** manager, Manufacturing and Parts Service Div. **Anthony A. Tocco** has been named corporate value engineer.


Seifert

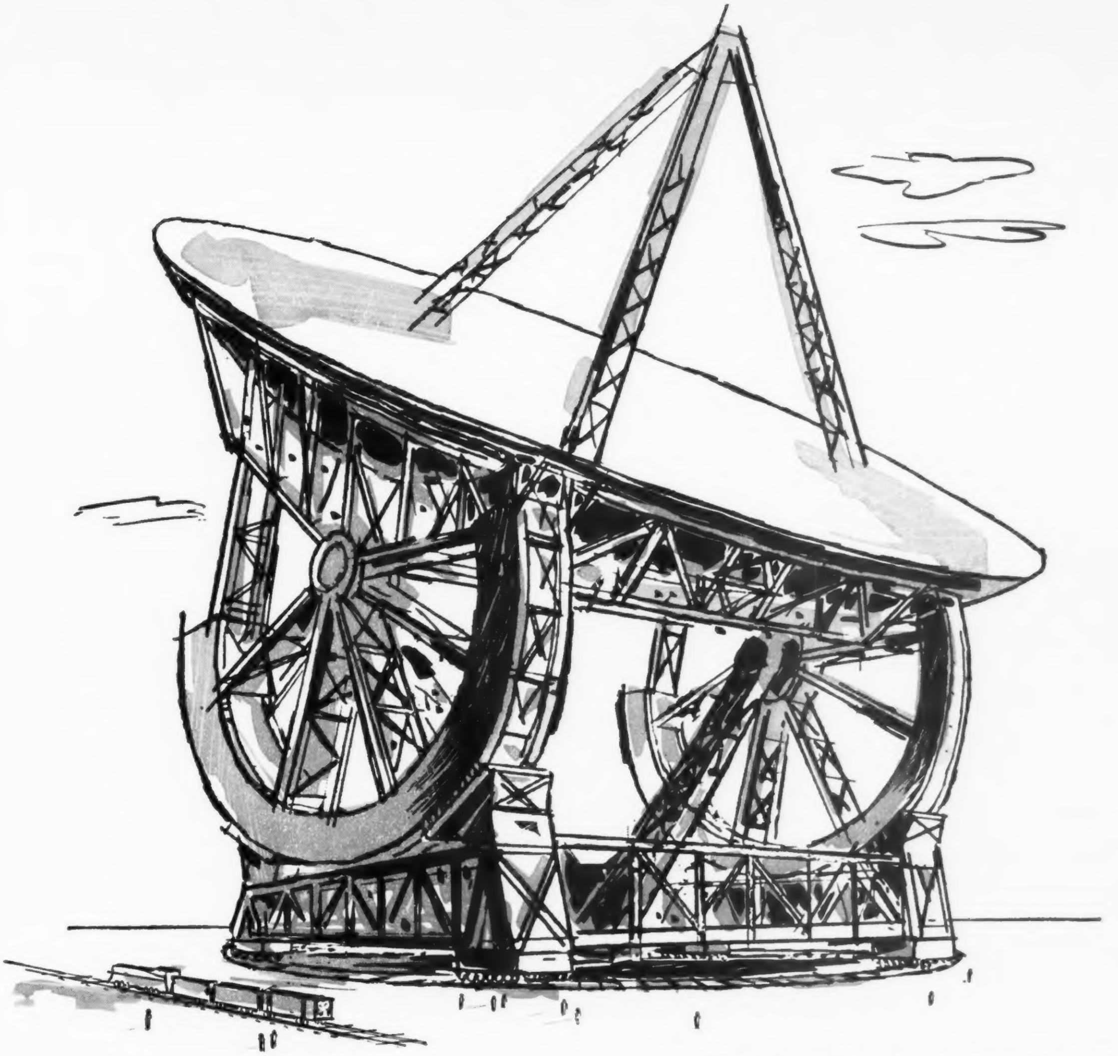

Davis


Canright


Wilcox


McCall


Lewis



Huge radio telescope for celestial exploration and space communication. Note how freight train is dwarfed by it.

Simons

Hall

Danyow

Fink

Warner

Locke

John C. Simons, director of National Research Corp.'s Applied Physics Dept., will head the company's new Space Vacuum Laboratory.

Albert C. Hall, director of research and engineering for The Martin Co., has been promoted to vice-president of engineering. **George S. Trimble Jr.,** has been named corporate vice-president for advanced programs; **Jack B. Gilbert,** quality control manager, Titan fabrication; and **Justin L. Bloom,** project engineer for Advanced Snap Programs in the Nuclear Div.

Ford Motor Co. has established a Defense Products Group under the direction of **Gerald J. Lynch,** company vice-president and general manager of Aeronutronic Div.

Richard F. Hughes has been appointed assistant chief engineer, aeroballistics, for Chrysler Corp.'s Advanced Projects Organization.

Charles E. Dolberg has been elevated to director-systems management for Philco Corp.'s Government and Industrial Group. **Rear Adm. Richard Holden** (USN-Ret.) joins the Group as director of the Advanced Systems Development Dept., and **Winton O. Etz** as section manager, Integrated Data Systems.

T. C. Wisenbaker, general manager of Raytheon's Missile Systems Div., has been elected a corporate vice-president. In other appointments, **Charles W. Carruthers** becomes chief engineer for Electromechanical Components Operations, Industrial Components Div., and **Glen Wade,** associate director of engineering-general research for the Microwave and Power Tube Div.

Caswell B. Neal has joined Electro-Optical Systems, Inc., as a project supervisor in the Electronic Systems Div. **James D. Burns** and **Gerard R. Selg** have joined the Energy Research and Fluid Physics divisions, respectively.

S. E. Danyow has been appointed vice-president, Rocket and Ballistic Operations, Rocket Power-Talco Div. of Gabriel Co.

John G. Ziemann has been named chief metallurgist of Kelsey-Hayes Co.'s Metals Div. **Stanley Abkowitz** joins the division as manager of refractory metals products development.

Charles H. Sommer has been elected president of Monsanto Chemical Co.

Daniel J. Fink has been made vice-president, research, to head the new Research Div. at Allied Research Associates, Inc., and **Roger S. Warner Jr.,** vice-president, engineering, to head the new Engineering Div. **Arthur Winston** becomes chief scientist in the Research Div., and **Claude Brenner,** chief engineer in the Engineering Div.

Robert F. O'Neill has been promoted to manufacturing manager of Standard Steel Corp.'s Cambridge Div.

Harry A. Sandberg has joined Rosemount Engineering Co. as head of manufacturing.

James S. Locke, vice-president of Minneapolis-Honeywell Regulator Co., becomes vice-president and general manager of the Brown Instruments Div.

Lt. Gen. James M. Gavin (USA-Ret.) has been elected president of Arthur D. Little, Inc.

Sydney Shrage and **Andrew J. Kubic** have joined Thompson Ramo Wooldridge as senior project engineer and engineering specialist, respectively, in the Power Systems Product Development, Tapco Group.

Don Conroy, area chief, field liaison engineering, will head McCormick Selph Associates' new Los Angeles liaison office.

James Marmor has been appointed contract coordinator, Military Products Dept., Marketing Div. of Garlock Packing Co. He formerly was technical coordinator, Polaris program, at Lockheed's Missile and Space Div.

John F. Gall has been appointed manager of Pennsalt Chemicals Corp.'s new Research Products Development Dept., Technical Div.

Raymond S. Stewart has been named government liaison engineer for Texas Instruments, Inc., Metals & Controls Div., and for TI's nuclear-fuel-fabricating subsidiary, M&C Nuclear, Inc.

Kenneth H. Jacobs and **G. Daniel Brewer** have been appointed assistant vice-presidents of Grand Central Rocket Co. Jacobs is currently director of engineering.

George S. Vermilyea, former executive vice-president of Nems-Clarke Co., a division of Vitro Corp. of America, has been elected president of the division. **Vernon M. Setterholm** becomes vice-president; **Wayne G. Shaffer** and **John C. Geist** have been promoted to director and associate director, respectively, of the Silver Spring Laboratory.

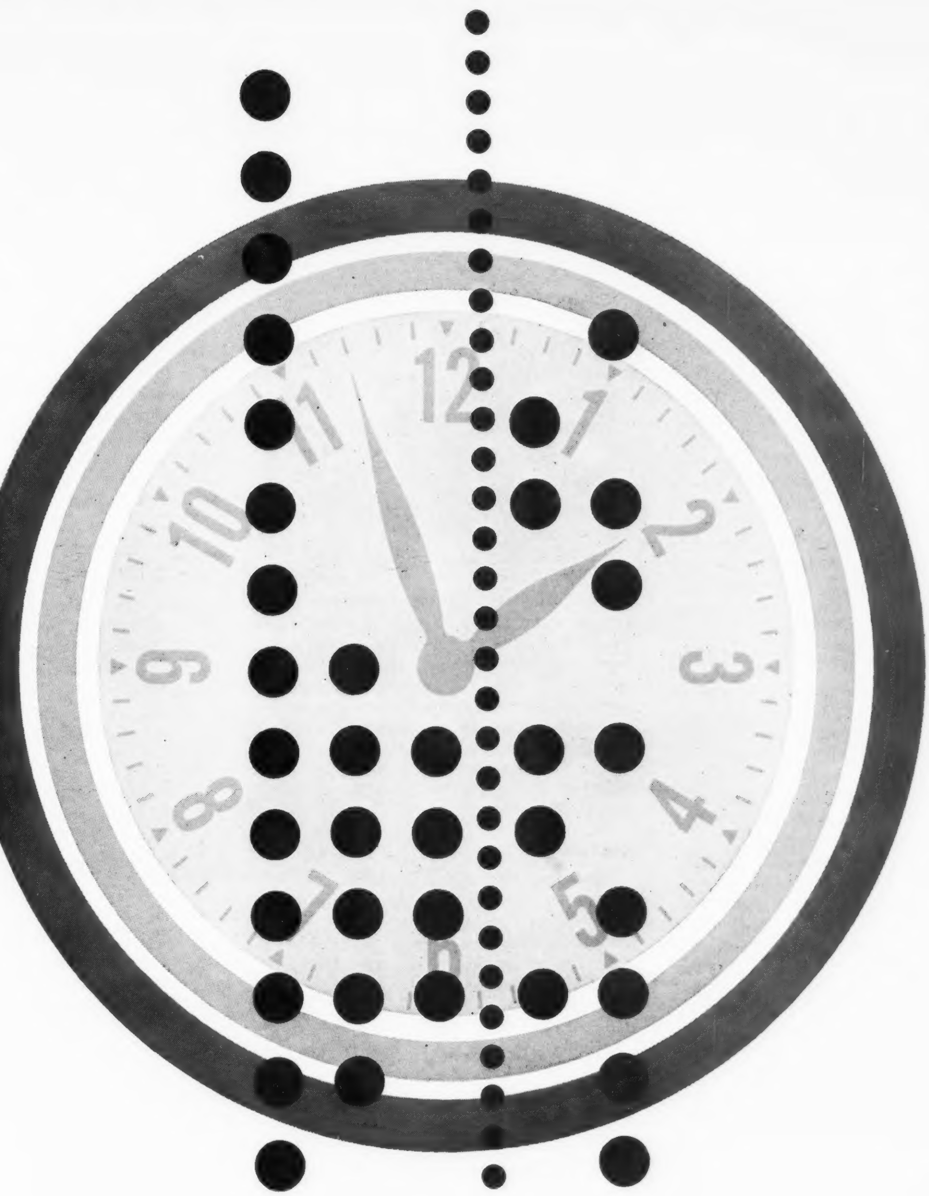
F. Hamilton Wright has joined the technical staff of Space Electronics Corp.

W. A. Kerr becomes manager of the new Military Products Div. of Bausch & Lomb Optical Co. **L. S. Packer** will head the Research and Engineering Dept. in the division, and **C. N. Hendershott,** Manufacturing Dept.

At the Pesco Products Div. of Borg-Warner Corp., **J. F. Murray** has been appointed director of engineering; **Thomas D. Carpenter,** manager, future product planning; and **Louis J. Schafer,** project manager.

In the Missile Products Div. of Beckman & Whitley, Inc., **Clarence H. Carlton** and **Ronald Lewis** have been named chief engineer and chief design engineer, respectively. In the R&D Div., **Howard Einhorn** and **Warren Wheeler** have taken charge of the model shop and test-site facility, respectively, and **Clarence Lykam** joins the group as engineering assistant on design and modification of instrumentation. **Fred W. Stang** has joined the Meteorological Products Dept. of the Instrumentation Div. as an applications engineer.

Herman Blumenthal has been appointed research director of Chromalloy Div. (CONTINUED ON PAGE 86)



ASTRONAUTICS Data Sheet — *Materials*

Compiled by C. P. King, *Materials and Process Section, The Marquardt Corp., Van Nuys, Calif.*

TITANIUM ALLOYS

Although titanium has been used in aircraft and missiles for little more than 10 years, it has already become an indespensable metal because of its light weight, high strength, and excellent resistance to corrosion. In this short time, over 20 alloys have been developed and the nonalloyed grades are still in use. Commercial and semicommercial titanium mill products fall into four classifications: Commercially pure, alpha-beta alloys, alpha alloys, and beta alloys.

Of the many alloys developed, the great majority belong in the alpha-beta group. The table shows the titanium grades of commercial interest. However, five specific compositions account for the larger part of the titanium used in aircraft and missile applications. These are compared in strength in the two graphs.

Fabrication

Commercially pure titanium is fairly simple to fabricate and is used where ease of fabrication is the primary consideration. In sheet form, most operations on the commercially pure form may be conducted cold, but the alloys of titanium need temperatures between 500 and 1000 F. Spinning, drawing, stretch forming, and rubber forming are all applicable.

Forging of titanium and its alloys is widely used. Titanium is more difficult to machine than conventional metals and, in general, low speeds, heavy cuts, and ample coolant should be employed.

Joining

Fusion welding of titanium requires considerably more care than most other metals. However, good welds may be obtained. Resistance welding offers no problem, and brazing is also used to a limited extent.

Castings

Because of the extremely reactive nature of titanium in the liquid state, the production of castings in this metal has been extremely limited. However, some castings are being made using consumable electrode arc furnaces and casting in vacuum into rammed graphite-mix molds. The 5Al-2.5Sn and 6Al-4V alloys have accounted for most of the castings poured, although the 13V-11Cr-3Al alloy is now being cast as well.

Applications

Titanium sheet alloys have found wide application in such parts as pressure vessels, rocket cases, skins, ducts, and shrouds. Bars and forgings are widely used for jet engine compressor components such as rings, blades, and spacer housings. Titanium alloys are also finding wide acceptance in the fastener industry, where screws, nuts, bolts, and rivets are being produced.

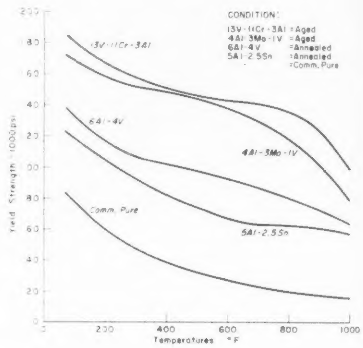
Physical Properties

The 13V-11Cr-3Al composition is the heaviest titanium alloy, with a density of 0.175 lb/cu in. The commercially pure grades and the other alloys vary between 0.160 and 0.163 lb/cu in. The coefficient of linear expansion of commercially pure titanium is 10.0 Btu/hr/sq ft/F/ft at 800 F. The alloys of titanium vary between 6.8 and 7.2 Btu/hr/sq ft/F/ft at 800 F.

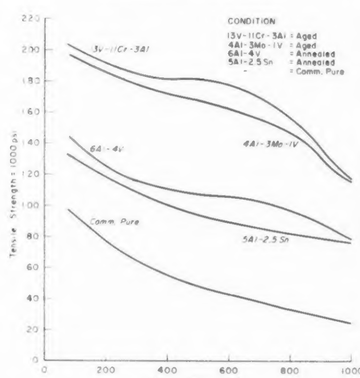
Available Forms

The 4Al-3Mo-1V alloy is available in the sheet form only. Commercially pure titanium and other commonly used alloys (5Al-2.5Sn, 6Al-4V and 13V-11Cr-3Al) may be obtained as sheet, plate, bar, wire, and forgings.

YIELD STRENGTH OF WROUGHT TITANIUM ALLOYS

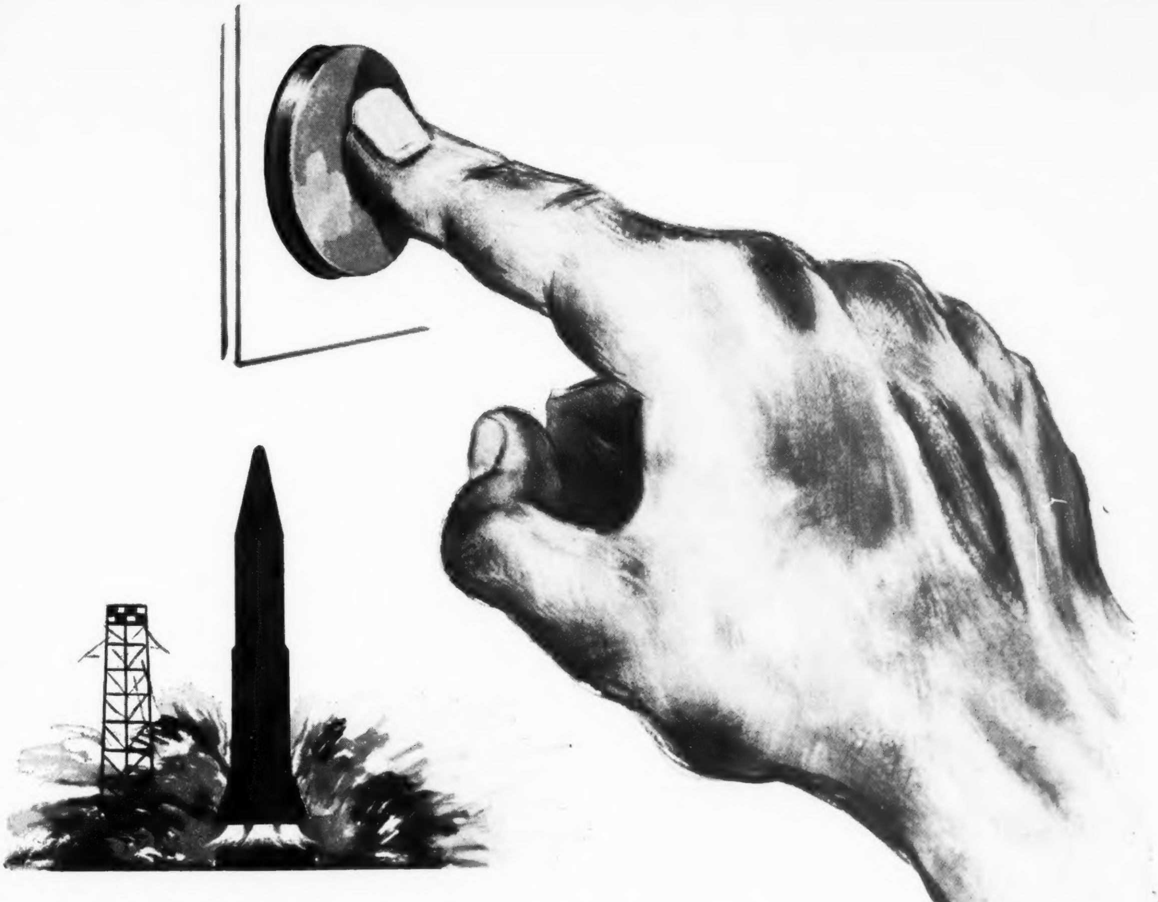


ULTIMATE TENSILE STRENGTH OF WROUGHT TITANIUM ALLOYS



Producer's Designations for Titanium Alloys

General Designation (Based on Chemical Composition)	Producers's Designation			
	Mallory-Sharon	Crucible	Republic	TMCA
	MST-40	A-40	RS-40	Ti-40A
	MST-55	A-55	RS-55	Ti-55A
Commercially Pure				Ti-65A
	MST-70	A-70	RS-70	
				Ti-75A
				Ti-100A
5A1-2.5Sn	MST-5A1-2.5Sn	A-110AT	RS-110C	Ti-5A1-2.5Sn
6A1-4V	MST-6A1-4V	C-120AV	RS-120A	Ti-6A1-4V
4A1-3Mo-1V	—	C-115AMoV	RS-115	Ti-4A1-3Mo-1V
4A1-4Mn	MST-4Mn-4A1	C-130AM	RS-130	—
8Mn	MST-8Mn	C-110M	RS-110B	—
5A1-2.75Cr-1.25Fe	—	—	RS-140	—
5A1-1.5Fe-1.5Cr-1.2Mo	—	—	—	Ti-155A
7A1-4Mo	—	C-135AMo	RS-135	Ti-7A1-4Mo
8A1-8Zr-1Cb + Ta	MST-881	—	—	—
13V-11Cr-3A1	—	B-120VCA	RS-120B	Ti-13V-11Cr-3A1



People in the News

(CONTINUED FROM PAGE 82)

Benjamin H. Ciscel has joined Vought Electronics, a division of Chance Vought, as general manager.

Thracy Petrides, former head of U.S. Industries' Military Systems Planning Group, has been appointed director of government programs.

Sven H. Dodington has been promoted to technical director of government projects at ITT Laboratories. **Martin Dubilier** has been elected president of ITT's International Electric Corp. division.

J. M. Schmidt, president of the recently formed Inland Research, Inc., specializing in solid rocket propellants, has announced the appointment of **David A. Fletcher,** as vice-president, technical director, and **George L. Graf,** as manager of product engineering.

Adm. Sherman E. Burroughs Jr. (USN-Ret.) has been named special assistant to the president at Librascope Div. of General Precision, Inc.

William H. Emerson has been appointed technical manager of microwave absorbing materials for the Sponge Products Div. of B. F. Goodrich Co.

Joseph B. Rice Jr. has been named general manager of Burroughs Corps.' new ElectroData Mfg. and Engineering Div.

James A. Burns and **Nazzareno P. Cedrone** have been appointed director of long-range planning and technical director, respectively, of the Systems Div. of Bendix Aviation Corp.

Stan Burns has been named director of engineering, American Electronics, Inc., Ground Support Div. **Frank E. Swatek** has joined the company as a staff consultant.

Archer E. Mohr has been named manager, production engineering, of RCA's management staff at Mountaintop, Pa.

Arthur W. Keough has been appointed quality control manager of the Los Angeles division of Avnet Electronics Corp.

Samuel Feinstein is the new manager of the Applied Research Laboratory at Servomechanisms, Inc.

Varian Associates has appointed **Paul B. Hunter, Theodore Moreno,** and **Emery H. Rogers,** vice-presidents of patents, Tube Div., and Instrument Div., respectively.

R. C. Jones has been named acting


Ciscel


Petrides

supervisor of the new Plasma Physics Branch established at the Physical Sciences Laboratory of Melpar, Inc.

William W. Wood Jr., formerly vice-president, simulator engineering, Link Div. of General Precision, Inc., has been elected executive vice-president, development and engineering and also has been named a director of GPI. **Hugh M. Williams** becomes vice-president in charge of Link's Western Laboratories; Edward W. Sheridan, manager of Eastern Laboratories.

George E. Holbrook, vice-president, director, and executive committee member of E. I. du Pont de Nemours & Co., has been elected vice-president of the Engineers Joint Council.

HONORS

Eugene Stone Love, assistant chief of NASA's Aero-Physics Div., Langley Field, Va., has been selected by the National Civil Service League to receive an award as one of the top ten career men in the Federal government for 1960.

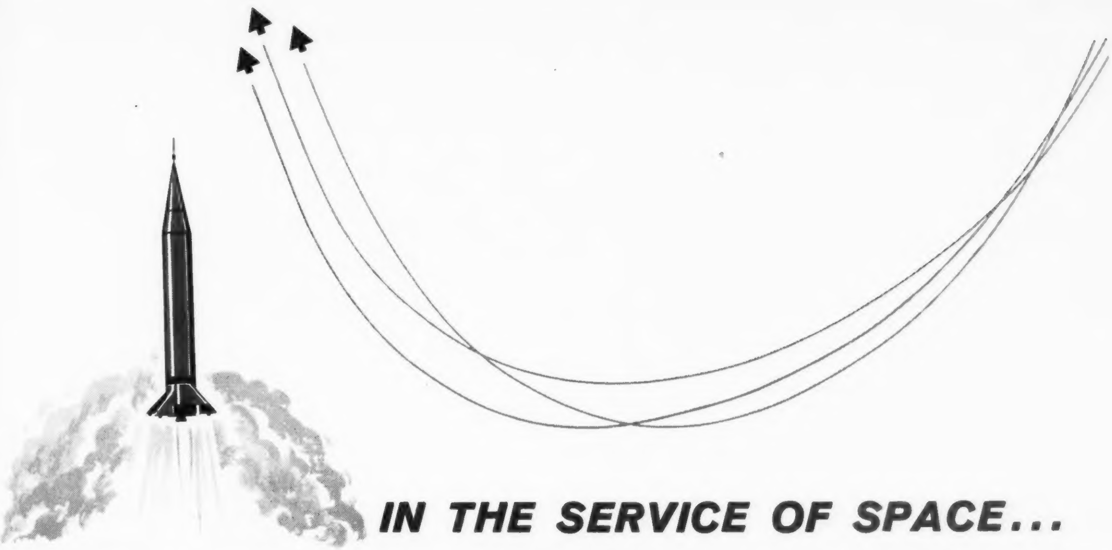
Kenneth A. Norton, chief of Radio Propagation Engineering Div. at Boulder (Colo.) Laboratories of the National Bureau of Standards has been named to receive the 1960 Harry Diamond Memorial Award of the IRE for "contributions to the understanding of radio wave propagation."

The second annual Republic Aviation college scholarship award has been won by a 17-year-old East Islip high school senior, **James H. Rillings.**

♦♦

Underwater Nuclear Jet Engine Patent Applied For

A patent application on a nuclear jet engine (turbo or ram) for propelling submarines and surface vessels has been filed with the U.S. Patent Office by Boeing Aircraft in the name of L. J. McMurtrey of its advanced engineering group. According to the patent application, a submarine with a 2-ft-diam-nozzle engine could travel at more than 100 mph.



Telebit

(CONTINUED FROM PAGE 27)

relatively crudely in the first rocket boosts and then successively improve the accuracy of the flight path by introducing small velocity corrections as the vehicle moves toward its goal. With plenty of time available, it is possible to make a number of measurements of the position of the vehicle and essentially integrate over the sum of the measurements before introducing a vernier correction. This smoothing of the apparent position of the vehicle permits a marked reduction in the single-point accuracy requirements of the tracking equipment.

Relatively Few Functions

The information rate required for telemetry in space vehicles is considerably less than that associated with the remote control of the flight of aircraft or missiles, both of which incorporate a large number of rapidly changing functions which must be monitored on the ground. The normal bandwidth for missile telemetry may involve hundreds of kilocycles of channel capacity and tens of kilobits of information capacity. In the case of the space vehicle, however, the number of functions to watch is relatively few, and changes relatively slowly. The information transmission rate is at least an order of magnitude below that of missiles. As a matter of fact, because of the length of time a space vehicle must be monitored, an information transmission rate comparable to a missile's would soon saturate any data recording and reduction center on earth.

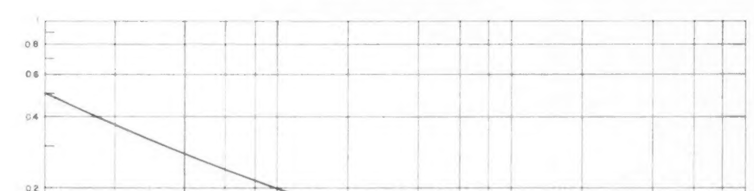
In guiding an aircraft or a missile from the ground, we need real-time commands and a means for immediately sensing the response to these commands. But we can take half an hour to transmit a command to the space vehicle, and we can monitor the response on a similar time scale. Thus a considerable simplification in the command structure of the system is possible. On the other hand, the number of different commands that need to be sent to a space vehicle is considerably larger than required for normal guidance of a missile or aircraft. In addition to steering the space vehicle, we need to turn transmitters on and off, alter the function of experimental apparatus, or change bandwidth or pulse rate of telemetry. Explorer VI, as a case in point, employed 14 separate commands.

The fact that the space vehicle must operate for a comparatively long time forces its total energy requirement to be very much larger than that of a missile. Thus an important consideration in space vehicles is to minimize the power (and the weight that goes linearly with power) needed by the vehicle's equipment, and in fact this goal becomes the overriding concern in most of the presently designed or contemplated space probes.

All of these factors, then, lead to the possibility and the need for an integrated telemetry, tracking, and command system.

Pioneer I, launched in October 1958, was the first space probe to use a partially integrated system. The vehicle receiver was phaselocked to a ground receiver, and the coherent transmitter in the vehicle could be modulated for telemetry on command. The development of the later vehicles in this Able series (Explorer VI and the two Able-4's) resulted in a fully integrated system, incorporating both airborne and ground equipment. The system had to meet five requirements: Minimum airborne power, light weight (in the vehicle), long life, high reliability, and an operating range of 50 million miles. In addition, the ability to vary the information rate on command was incorporated, so that the relatively large amount of information which can be transmitted at close ranges is reduced as range increases to maintain a usable signal-to-noise ratio.

Smoothing-Time Effect on Accuracy of Midcourse Tracking in Venus Trajectory



Telebit Principles

Let us look first at certain principles underlying the Telebit system.

Of the six parameters which describe uniquely the trajectory of a space vehicle (elevation, azimuth, range, and rate of change of these), independent and repeated measurements of any three will suffice to obtain the ephemeris of the vehicle. In theory, three independent measurements of velocity are sufficient if simultaneously made from separate points on the earth, although it is more practical to make measurement of three parameters from one ground site. You can measure, for example, one angle, the range, and the velocity; or two angles and the range. It turns out that for space systems, the measurement of two angles and the velocity leads to the best integrated system. The angles are obtained from the elevation and azimuth angles of the ground antenna as it tracks the vehicle, and the radial velocity is obtained from the Doppler shift of the received signal.

To obtain and apply these measurements involves a ground transmitter and receiver, a sensitive directional antenna on the ground, an airborne transponder, and a computational center geared to take these data over a period of time and integrate the point-by-point measurements to provide a smooth trajectory. In addition, the center must calculate the difference between the existing and the desired trajectories and determine what increment of velocity needs to be applied at what moment to make the vehicle arrive at a given point in space at a given time. Once these calculations have been made, you have to be able to transmit the appropriate commands to the vehicle and the vehicle must have means to translate these commands into the correct action. Two basic characteristics which follow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space and in the air, on land, on sea, and in the ocean depths—wherever advanced ctronics plays its part—you will find dramatic proof of Philco leadership in hnology, capacity and versatility. For here is an organization fully staffed and ly equipped to pioneer and contribute in every phase of the art . . . to solve e most complex problems . . . to create totally new devices . . . to manufacture e finest electronic products and systems.
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rra Electronic Division • Western Development Laboratories
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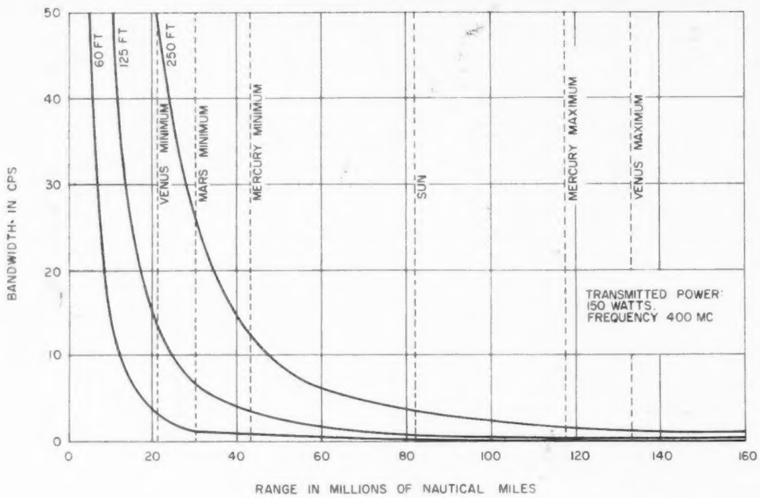
Information Bandwidth vs. Range for Three Ground-Antenna Sizes



from this navigation system are that the brains—the complexity needed for interpretation, calculation, and forecasting—and the beef needed for making tracking measurements remain on the ground.

The accuracies made possible by such navigation of a space vehicle, relying as it does on smoothing trajectories over fairly long periods of time, are best illustrated by specific examples. R. C. Booton of STL has calculated the reductions in trajectory errors made possible by smoothing time for two missions. For a vehicle in a circular orbit about the earth at an altitude of approximately 20,000 miles, the period of the orbit will be known to within 21.5 sec after only 6 hr of tracking and to within 3 sec after 48 hr of tracking, assuming one set of measurements every hour. If one set of measurements is made every 5 min, the period is known to within half a second after 48 hr. A similar accuracy could be obtained by the hourly measurements, of course, if the time of tracking were extended to 576 hr. Booton assumed angle measurements here to an accuracy of 1 milliradian and velocity to 1 fps, both of which are within the capability of present equipment. The graph on page 88 shows the phenomenal increase in tracking accuracy obtained by smoothing on a ballistic trajectory to Venus. For this mission, the accuracy of the vehicle's velocity can be known to within 0.05 fps after 100 days of tracking, although initially it is known to only 1 fps.

The fundamental parameter of space communication is the energy per bit of information to be transmitted; and the fundamental limitation on communication is the effective power that can be used in the system. This basic limitation divides itself into two types of problems: The generation, transmission, and reception of power on the one hand and the method of modulating this energy so that it carries the information.

Determining Factors

The type and quantity of information, of course, is determined by the particular space mission and the requirements of the experiments to be performed. The rate of transmission is determined by the amount of data processing which is carried out in the vehicle. The power in a low-altitude earth satellite is sufficiently high and the range is sufficiently small so that sophistication in either modulation techniques or in data processing in the vehicle is not needed. But, as shown in the graph above here, there is a sharp decrease in bandwidth at interplanetary ranges, necessitating a large degree of sophistication of data processing in the interplanetary probe if significant information is to be transmitted. From another aspect, the rapid motion of low-altitude satellites with respect to the ground requires ground antennas of low directivity but also a large number of ground stations if continuous coverage is to be achieved. Lunar or interplanetary vehicles require no more than three ground stations for continuous coverage, but they do need highly directive antennas.

The basic limitations on ground reception are choice of frequency and of preamplifier, since the limitation of background noise against which the communication system must operate is imposed by these factors. Although, in general, the higher the operating frequency the less the noise, this must be weighed against the limiting fact that the higher the frequency the more critical is the precision of the antenna dimensions and the more weight must be flown to compensate for reduced operating efficiencies. The use of parametric and maser preamplifiers in ground receivers has now reduced the noise from that source well below that relating to frequency, and thus the limiting noise is determined principally by the antenna. Balancing all effects, frequencies between 400 and 2000 mc appear to be optimum for space communications.

Finally, the need for high power in the ground transmitter for sending commands to the space vehicle has established the need for diplexing elements of very high isolation and low loss, since the same large directional antenna must be used simultaneously for reception of the signal (at about 10^{-12} microwatt) from the space vehicle. Such diplexers are installed at the Jodrell Bank antenna in England and at the Kanae Point station in Hawaii.

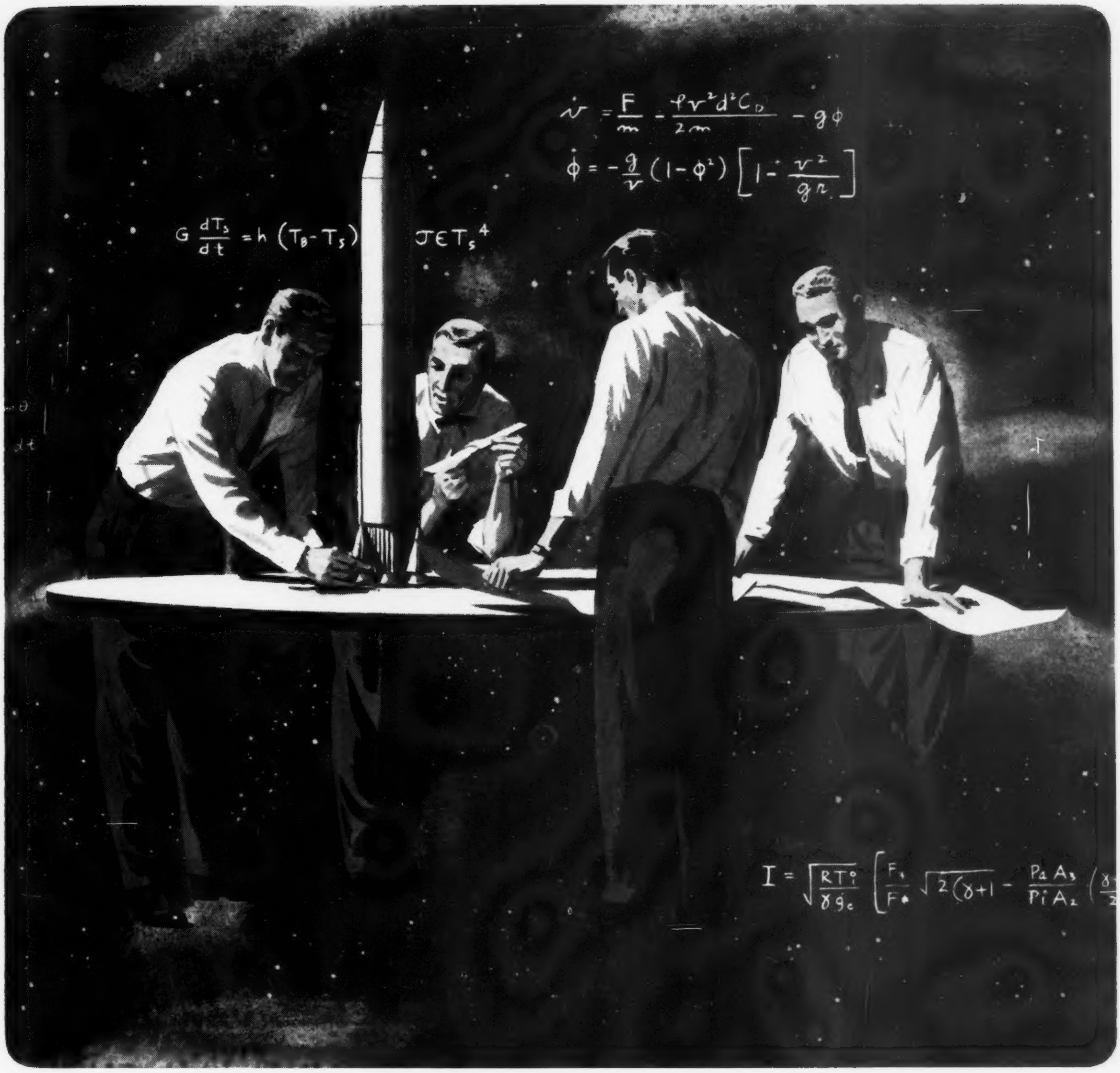
Present limitations in space vehicles on weight and power necessitate intermittent telemetry operation. For interplanetary ranges, available power permits transmission to the ground for only a fraction of the time. Thus it is desirable to store measurements in the vehicle, and readout when the transmitter is operated. The storage of information and the need for very narrow bandwidths lead to the choice of a digital telemetry system. The digital system, in addition, provides quantized information which may be retransmitted without degradation and which is easily processed by large computers.

A final problem in the integrated system is the mode of transmission of commands. Since there are a large number of commands and the time of transmission may be long, a digital command system making use of a biphase-modulated subcarrier is feasible, and close examination indicates that it approaches the ideal command system.

Systems for Space Probes

Let us turn now to the system that has been devised for such probes as the Pioneer V now coursing on nearly an interplanetary trajectory to Venus.

The major design objectives of the Telebit space navigation and communication system were six in number: (1) tracking, command, and telemetry functions had to operate out to ranges of 50 million miles; (2) a six-


$\dot{v} = \frac{F}{m} - \frac{\rho v^2 d^2 C_D}{2m} - g\phi$
$\dot{\phi} = -\frac{g}{v}(1-\phi^2)\left[1-\frac{v^2}{gr}\right]$
$G\frac{dT_s}{dt} = h(T_B - T_s)$
$\sigma \epsilon T_s^4$

month lifetime was desired; (3) simplification of the probe itself was to be traded for complication on the ground; (4) both analog and digital measurements had to be telemetered; (5) ground data handling and processing of both tracking and telemetry had to be reliable and uncomplicated; and (6) the system had to be adaptable to varied space missions.

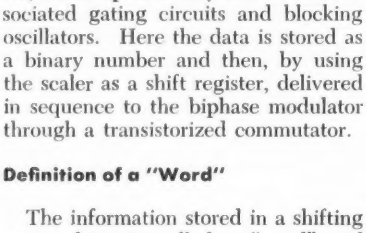
The digital telemetry unit, which is the basis of Telebit in the flight vehicle, is shown in block diagram at bottom. This system was designed to store the maximum amount of information accumulated during transmitter "off" times while permitting efficient transmission of variations in measurements during the relatively brief "on" times.

For Explorer VI, 24 separate kinds of information were gathered, stored, and transmitted by Telebit. Of these 24, which are listed in the table on page 27, only six are discrete occurrences and thus naturally digital. The remaining 18 are converted to a binary code by comparing the continuous voltage output from an analog measurement against a digital ramp, using clock pulses to measure the time and hence the amplitude at coincidence. The digital measurements are then applied to a shifting accumulator, made up of binary scalers and associated gating circuits and blocking oscillators. Here the data is stored as a binary number and then, by using the scaler as a shift register, delivered in sequence to the biphase modulator through a transistorized commutator.

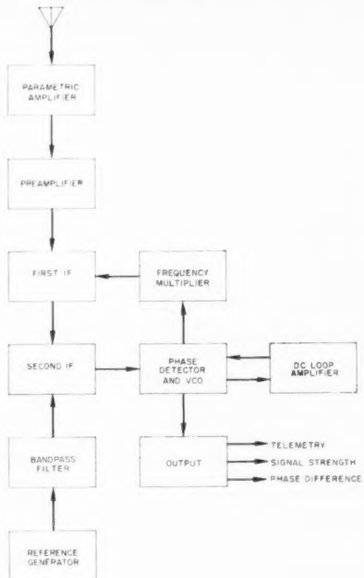
Definition of a "Word"

The information stored in a shifting accumulator is called a "word" and the commutated sequence of all words is called a "frame." In Telebit, one word is composed of 10 information pulses, or bits. The number of words composing a frame is determined by the number of experiments. In Explorer VI the frame included 10 words. In addition, synchronizing pulses are inserted to expedite ground decommutation. Two synchronizing pulses always having the same form are added before each word and one synchronizing word is added before each frame. Thus an entire word consists of 12 pulses and an entire frame of 11 words.

Block Diagram of Digital Telemetry Unit for Flight Vehicle



Simplified Block Diagram of Ground Receiver



The information from the experiments listed in the table on page 27 is transmitted by the Telebit system as shown in the format of the table on that page. Word No. 10 in this table subcommutates items 10 through 24 in the first table, since these 15 measurements change slowly with time and one sample every 16 frames is sufficient to characterize them to the accuracy desired. With the three pulse rates at which Telebit can be readout on command—1, 8, or 64 bits per sec—approximately 132, 17, or 2 sec are required to transmit one frame.

The command receiver is a transistorized, double-conversion, phase-lock-loop unit which produces a coherent output at a rational fraction of the received frequency. It can be operated, on command, with either a 250- or 40-cps bandwidth. It operates continuously; and, since its bandwidth is less than the frequency uncertainty of the received signal, it repeatedly sweeps over a range of 30 kc searching for a carrier. When the receiver acquires and locks-on a signal from the ground, the sweeping stops and the receiver can then accept any of 30 possible commands. In its role as transponder, the same receiver accepts a CW signal from the ground and delivers it to the transmitter for transmission to the ground.

Commands are recognized and delivered to appropriate circuits in the vehicle by the command decoder, which responds to the sequence of biphase modulated pulses supplied by the receiver. The decoder performs a parity check on the received signal, and therefore starts its sequencing from the first sync-pulse of the digital command message.

Five-Watt Transmitter Used

The transmitter, which weighs about a pound and operates at an efficiency of 15 percent, accepts an RF signal from the receiver, multiplies it eight times in frequency, and amplifies it to a 5-watt level. In the process, the signal is modulated with a 1024-cps subcarrier containing the time multiplexed pulse-code-modulated output of the telemetry system. Biphase modulation is employed to impress the telemetry output on the subcarrier. For long ranges, this 5-watt transmitter is used to drive a 150-watt transmitter.

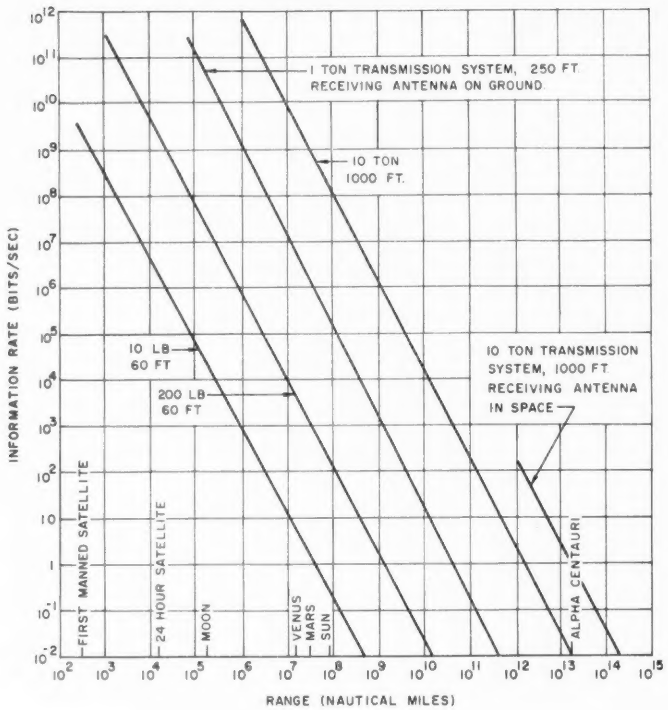
On Explorer VI these four flight units of the system weigh less than 20 lb and require 45 watts. As has been noted, each of the four is a functional part of the separate goals of tracking, telemetry, and command.

The consequences of the design philosophy of placing the burden of weight, power, and complexity on the ground are several. With a high-power ground transmitter and very sensitive ground receiver, the corresponding flight receiver and transmitter can be less sensitive and less powerful, and therefore light in weight and relatively simple. Since the ground equipment can be repaired, the inclusion of most of the system complexity, and hence of possible malfunctions, at ground installations serves to increase over-all system reliability.

For the Span Network, tracking, telemetry, and command functions are provided by four stations, located at Cape Canaveral, Manchester, Singapore, and Hawaii, with Manchester and Hawaii conceived as the principal stations, since their larger antennas permit tracking to the farthest ranges. Although there are differences among the stations, the role of the station in the tracking, telemetry, and command system can be shown by using Hawaii as an example.

The principal antenna (see photo on page 27) at the Hawaii station is a 60-ft parabolic, directive antenna used both for transmitting and receiving. Once the station has locked on the signal from the vehicle, tracking in angle is performed with the antenna by nodding it alternately in elevation and azi-

Information Rate vs. Range for Future Systems



muth. Separate measurements to 0.1-deg accuracy every 2 or 3 min are possible by this means. In addition to the parabolic antenna, a five-element helical array is also used. Unlike the paraboloid this is fixed in frequency, but it is remotely steered in the same fashion. Gain of these antennas at 400 mc is approximately 34 db for the paraboloid and 25 db for the helix array.

Doppler measurements are made possible by comparing the carrier transmitted to the space vehicle with the carrier coherently transponded in the vehicle and returned to the ground. The signal is offset in frequency to permit separation on the ground, but removing the offset on the ground permits the automatic readout of the two-way Doppler shift. This permits the measurement of the vehicle's velocity to 1 fps.

A phaselocked-loop receiver and correlation detection is used on the ground. With this equipment a telemetry signal heavily masked in noise can be recognized by comparing the received modulation with a reference modulation generated in the receiver. A block diagram of the receiver is shown on page 92.

The minimum detectable signal is −160 dbm at the ground antenna. Preamplification is provided by a parametric amplifier with a noise figure of about 2 db.

The digital information in the output of the receiver is decoded and punched onto paper teletype tape, along with interlaced time signals based on a very stable crystal oscillator accurate to one part in 10^7. The perforated tape is used to teletype quick-look data to a control center in Los Angeles.

The ground transmitter derives its frequency from the same oscillator and, through a conventional chain of modulators, multipliers, and power amplifiers, supplies 10 kw to the diplexer. The diplexer separates the received and transmitted signals going from and to the antenna.

Command Link Satisfactory

During the two months that contact was maintained with Explorer VI, operation of the command link to the satellite was quite satisfactory. For example, the satellite's 5-watt transmitter was commanded 59 times, for periods ranging from 2 to 86 min. Telebit was readout at 1 and 64 pps to check its operation, although 8 pps was the normal information rate. The television system was commanded 16 times.

Tracking operations were quite successful. Doppler and angular measurements were relayed to Los Angeles from Florida immediately after launch, and 5 min after burnout additional measurements were being received from Manchester, England. Within an hour after launch the trajectory of the satellite was known accurately enough to make the decision that the orbital-adjustment rocket need not be fired.

The effect of smoothing on the accuracy of tracking of Explorer VI was notable. Substantial reductions in the error with which the initial orbit was known occurred during the first few hours after launch. The knowledge of the position of the vehicle was known to within less than 1 n.mi. after 18 hr, the azimuth to within 0.1 deg, the angle of velocity vector at burnout to within 0.005 deg, and the velocity to within 0.03 fps. These same parameters had been known respectively to within 47 n.mi., 4 deg, 1 deg, and 162 fps after the first half-hour or so of tracking.

Telebit Test Results

On Explorer VI, Telebit information was redundant to data supplied by an analog system like the one carried in Pioneer's I and II. Data from the two telemetry systems showed no significant disagreement; but a few hours after launch the subcommutated measurements in word 10 of Telebit began to disagree consistently with the same measurements provided by the analog telemetry. Analysis indicates that the Telebit readings are probably correct.

We can look at the micrometeorite count as an example of the readout of experimental results by Telebit. The micrometeorite detector counts the number of particles which strike a diaphragm on the shell of the satellite, and separates these counts into two groups by the use of two threshold levels. Word 3 of the digital frame uses its first three bits for the high-momentum counts (particles with energy level of 5×10^{-3} gm-cm/sec or higher), which are divided by two before insertion, and the remaining seven bits for low-momentum counts (particles below that energy level down to the minimum detection threshold of 5×10^{-4} gm-cm/sec), which are divided by four before insertion.

When Word 3 reads 01′000′110-1001, as it did for 19 min on August 7, and does not change during that time, we know that no hits occurred during those 19 min and that 4 × 105, or 420, low-momentum hits and no high-momentum hits registered from liftoff to that time. When the register changes from 01′001′1110101 (117 low momentum and 1 high momentum register) at one readout to 01′011′000-0100 (4 low momentum and 3 high

momentum) at the next readout, as occurred early in September, we know that 60 additional low impacts have taken place in the interval (since the low-momentum scaler recycles at 128) and also 2 high-momentum impacts.

Although the integrated space navigation and communication system meets the original goal laid out for it and although it operated satisfactorily with Explorer VI, several steps remain to be taken. The Pioneer V launch will attempt to test the system out to its maximum range of 50 million miles, and effort should be directed to extending that range and the utility of the system.

Two promising avenues for futher investigation in the telemetry unit are the use of biphase modulation of the carrier, with a resultant signal-to-noise improvement of approximately 8 db, and the use of multiple bit encoding, which should further improve the modulation efficiency.

Another general area of improvement in the application of the Telebit system involves expanding analysis or processing of the experimental data before transmission. For example, in the present Telebit system the micrometeorite count is stored for a period of 6 to 10 hr, and thus the transmission from the satellite to the ground provides an average rate for these hours and, then, as the experiment is readout again, the average rate for a $2^1/_2$-min interval. A relatively simple change in the digital circuit logic would permit a record during the 6-hr period of the maximum counting rate that occurred in any one of the $2^1/_2$ min intervals, the minimum counting rate that occurred in any of the $2^1/_2$-min intervals, and the time at which these maximum and minimum rates occurred—in addition to the average count for the entire period. By skillful application of such satellite data processing, considerable increase in the amount of information obtained from micrometeorite experiments can be achieved without increasing the requirements on the total information-channel capacity.

Moreover, as data is accumulated, the experimenter will be better able to define the steps required for the analysis of the data. At this point it will be possible to program the ground computer to perform the mechanical part of the data analysis in addition to its present task of data reduction. This ability to approach the ideal of real-time analysis of experimental data is perhaps the most important single characteristic made possible by the digital telemetry system.

The sensitivity of the flight receiver can be improved with present techniques; but since the receiver is now within a few decibels of its theoretical limit, not a great deal can be anticipated in this area.

Directional Antennas

A large step can be taken, however, with directional antennas on the space vehicle. If we assume the best parametric amplifiers in the ground receiver and equal division of weight between antenna and transmitter in the vehicle, the characteristic parameters of a space-communication system may be combined to give the performance summarized in the graph on page 94. Here information rates possible with foreseeable space-communication systems are plotted against range. As can be seen, very large amounts of information can be transmitted rapidly from earth satellites with only 10 lb devoted to the transmission system in the satellite and a 60-ft antenna on the ground. A 200-lb system can transmit 10^7 bits per sec, or a television picture, from the moon. For transmission from a satellite orbiting Mars or Venus, the 200-lb system would permit 100 bits per sec over the entire path of Mars if a 250-ft antenna were used on earth. Transmitting video from this range would require between 1 and 10 tons of equipment in space and ground antennas between 250 and 1000 ft in diam.

Interstellar ranges bring tremendous problems. Even with a 10-ton transmission system and a 1000-ft receiving antenna on earth, the information rate from the nearest star is so low (1/100 bit per sec) and the required oscillator stability so high (one part in 10^{12}) that such a mission cannot be said to be within the state of the art.

However, with a 1000-ft receiving antenna placed in a satellite orbit about earth to eliminate atmospheric attenuation and ground sidelobe reflections, interstellar communication becomes a real possibility. Such an antenna is not the incredible engineering feat it might seem at first glance. The antenna could be constructed of heavy aluminum foil, with its over-all mass a small fraction of the equivalent on earth. With such an antenna in a 5000-mile earth orbit and the 10-ton transmission system also in space, an information rate of 1 bit per sec would be possible from Alpha Centauri. ♦♦

Movie on Free Radicals For Students

The National Bureau of Standards (Office of Technical Information) has available for loan or purchase a 13-min color movie (16 mm) explaining free radicals and free-radical research.

ASTRONAUTICS Data Sheet — *Propellants*

Compiled by Stanley Sarner

Flight Propulsion Laboratory Dept.

General Electric Co., Cincinnati 15, Ohio

PENTABORANE

Pentaborane is a colorless liquid with a characteristic pungent odor which has been described as "sickeningly sweet." The compound should not be confused with the other existing B_5 boron hydride, B_5H_{11}. This latter compound is unstable. The structure of B_5H_9 is a tetragonal pyramid with an H atom attached to each boron, and a "bridge" hydrogen between each neighboring pair of basal boron atoms, but slightly below the B_4 plane.

Hazards

Pentaborane is extremely toxic; more so than hydrogen cyanide. Every precaution should be taken to prevent leakage, and self-supplying gas masks should be used. A concentration of 14 ppm for 2 hr will cause immediate death in mice. A tentative maximum allowable concentration of 0.01 ppm has been adopted for workers under exposure for an 8-hr day. Contact with the eyes or skin should be avoided, although the fuel is not particularly toxic by skin absorption if washed off immediately. Safety goggles, neoprene gloves, rubber boots, and flame-resistant overalls should be worn. The median detectable concentration is 2.5 mg/m^3.

There is also a hazard due to the fact that pentaborane exposed to air is flammable and sometimes pyrophoric. Small residues and spills may be decomposed safely with methanol or a 1:1 solution of methanol in water. Chlorinated solvents, and particularly CCl_4, highly oxygenated solvents, carbon disulfide, and solvents with reactive carbonyl groups, such as acetone or other ketones or aldehydes, should be avoided, since shock-sensitive solutions may be formed.

Materials for Handling

Satisfactory metals for use with B_5H_9 include anodized aluminum, brass, copper, lead, mild steel, and stainless steel. Nonmetallic materials which are satisfactory include dry asbestos, Hycar rubber, polyethylene, Garlock 230 packing, glyptal sealant and, most probably, Kel-F and Teflon. Materials which are compatible with HEF fuels will probably suffice for pentaborane.

Cost and Availability

Pentaborane is available in pilot-plant quantities and possibly larger amounts, but is normally supplied by the Government. The price is very high (over $100 per pound) but would drop to a more reasonable amount in larger than laboratory quantities.

Physical Properties of B_5H_9

Boiling Point	60.06 C	140.11 F
Freezing Point	−46.75 C	−52.15 F
Critical Temperature (estimated)	227 C	441 F
Density at 0 C (32 F)	0.644 g/cm^3	40.2 lb/ft^3
at 25 C (77 F)	0.623 g/cm^3	38.9 lb/ft^3
Vapor Pressure at 25 C (77 F)	0.279 atm	4.10 psia
Viscosity at 0 C (32 F)	0.40 centipoise	—
at 25 C (77 F)	0.30 centipoise	—

Chemical Properties of B_5H_9

Heat of Formation (Liquid) at 25 C	+ 7.74 kcal/mole
Heat of Formation (gas) at 25 C	+15.02 kcal/mole
Heat of Vaporization at 25 C	7.28 kcal/mole
Heat of Fusion at Freezing Point	1.468 kcal/mole
Heat of Transition at −136.5 C	0.430 kcal/mole
Heat Capacity at 25 C	36.12 cal/mole-C
Maximum Allowable Concentration in Air (tentative for 8-hr day)	0.01 ppm

Theoretical Performance of B_5H_9*

	Specific Impulse (sec)		Chamber Temperature**
Oxidizer	Frozen Flow	Equilibrium Flow	Deg K
OF_2	339	367	5169
F_2	329	360	5101
O_2	313	327	4518
H_2O_2	309	316	3400
N_2O_4	293	306	4266
ClF_3	268	290	4487

* Pc = 1000 psia; Pe = 1 atm; optimum O/F ratio.

** Corresponds to equilibrium flow impulse.

Maser, Iraser, and Laser

(CONTINUED FROM PAGE 39)

ment before being used in the beam. It is noteworthy that no special action need be taken to put the molecules in the desired excited state; nature does this for us. The ability to store incoherently gained energy and to later emit it in coherent fashion is one of the most remarkable and important features of maser action. It offers the possibility of generating coherent radiation in the infrared and optical wavelength regions.

The ammonia maser oscillator makes a very stable and rugged driver for an atomic clock. Recently, the National Aeronautics and Space Administration gave Hughes Aircraft Co. a contract for laboratory development of such an atomic clock ultimately to weigh about 30 lb and suitable for use in a satellite. Its accuracy should be about three parts in 10^{11}, or 1 sec in 1000 years. The purpose of the satellite clock would be to check the General Theory of Relativity, which asserts that clocks should undergo gravitational time changes. A satellite would be in a gravitational field weaker than that at the surface of the earth. The satellite clock would be compared with a clock on the ground by telemetering.

How does the clock work? First, it is well to realize that the general principles of all types of atomic clocks are the same. That is, all use a vibrating atom or molecule to give the constant "ticking" of the clock. These ticks must be counted just as the hands on your watch count up and indicate the number of oscillations of the balance wheel of the watch. As the hands move around, they measure the flow of time proportional to the number of ticks. The virbrations of an atomic system are also counted, but by means of a servocircuit which synchronizes a quartz clock to the atomic vibrations.

What Makes It Tick

The maser clock, of course, uses the vibrations of the ammonia molecules. These molecules look like pyramids, having three hydrogen atoms at the base and a nitrogen atom at the apex. The nitrogen atom bobs up and down about 24 billion times a second. These are the ticks of the maser clock. Because of these vibrations the molecule broadcasts or emits these ticks as radio waves, which are available as output power from the maser oscillator. It is these radio waves which ultimately run the maser clock by driving the frequency divider which synchronizes the quartz clock.

The general relativity theory argues that a clock runs at a lower rate in a higher gravitational field; usually this is called the "red shift." Relativity theory changes our basic concepts of space and time, the framework used for all physical theories. The relativistic clock satellite experiment will therefore be of fundamental importance for our understanding of nature. When the relativistic clock satellite experiment is done, it will be possible to conduct additional experiments on geophysics and the velocity of light without adding equipment in the satellite.

Suppose another clock-equipped ground station is set up so that the satellite clock time signals can be received at both stations. The relativity measurements will automatically give the time the signals take to get to the stations. By triangulation, then, the distance between the stations can be measured in terms of the known velocity of radio waves (or light). Such measurements would give the exact geometric shape of the earth and could be made over inaccessible regions such as water or mountains. This experi-

ment can be reversed, and the velocity of light measured in terms of the distance between ground stations. This could be done in different directions in space over paths of thousands of miles, thus checking on whether space is the same in all directions—that is, whether it is isotropic. The velocity of light could be measured for different satellite speeds, and show whether it is independent of the motion of the source, as relativity requires. The maser clock can also be used for precision Doppler navigation of rockets.

While the beam maser makes a good frequency standard and atomic clock, it lacks the power output and tunability to make a good amplifier. Its low power is clearly the result of a relatively small number of molecules in the beam. By packing the molecules densely, as in a solid, the power output can be increased by factors of more than 10 million. In 1956, N. Bloembergen showed a way of doing this by using the properties of ions with spinning electrons in certain crystals to furnish the resonant, tunable transitions.

Although a crystal with two energy levels can be used to make a maser, the desired states can no longer be selected by physical separation of the ions, as in the case of the beam maser using a focuser. The solution to the problem of changing the thermal equilibrium distribution continuously is to use three energy levels instead of two.

A crystal is selected, such as ruby, with at least three energy levels unequally spaced. The electrons are continuously excited, or "pumped," from the bottom level to the top level by irradiation at the correct frequency. The population of the top level is thus made greater than the middle level, so that maser action (a net emission of power) can occur between these levels. In thermal equilibrium the population of the levels increases from top to bottom. When the outer transition is excited, a net absorption from the pumping field occurs, which at most can equalize the populations in these two levels because transitions can occur both ways. If the level separations are correct and unequal, equalization of the two outer levels can cause the top level to be more densely populated than the middle level.

The three-level maser can be described by analogy as similar to a water wheel in which water is continuously pumped up from a lower reservoir to the top of the wheel where it falls and generates power by turning the wheel. If the water is pumped up discontinuously and at random by using buckets to raise it from the lower reservoir to the upper one, where it is stored, the wheel can still be turned in a continuous manner. Similarly, a maser can be pumped by incoherent radiation, such as light, while still generating a continuous wave. At very high frequencies, the only available radiation-pumping generators are incoherent ones, such as infrared or optical sources. The maser technique thus presents the possibility of making coherent optical components, such as oscillators and amplifiers.

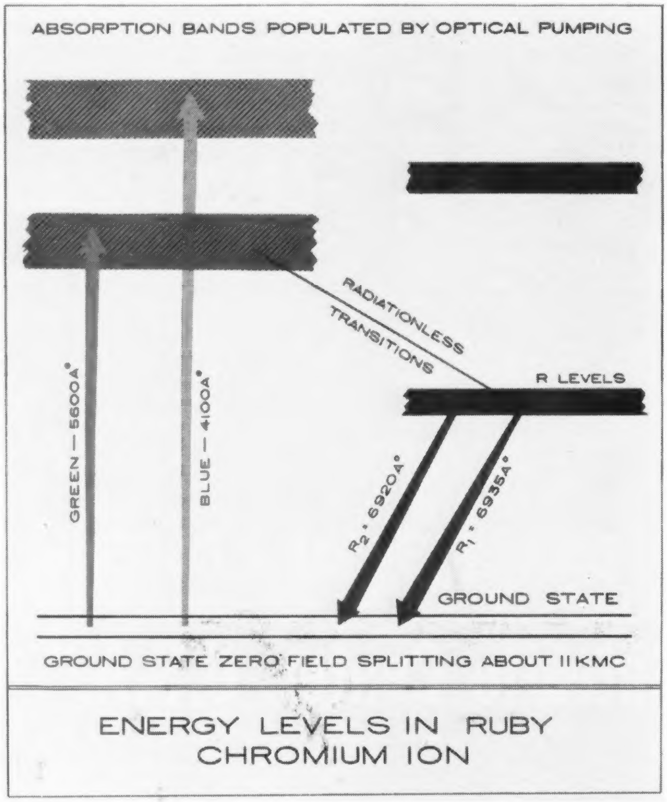
Cooling Key to Sensitivity

A solid-state maser amplifier is so sensitive because its crystal can be cooled to temperatures as low as desired (such as that of liquid helium) and all the ions emit in phase rather than at random. The cooling decreases thermal radiation noise, while the coherent emission of the ions stimulated by the signal to be amplified adds no noise to the amplified output. Signals a thousand times weaker than those handled by many electron-tube amplifiers can thus be amplified in a maser without being lost in background noise.

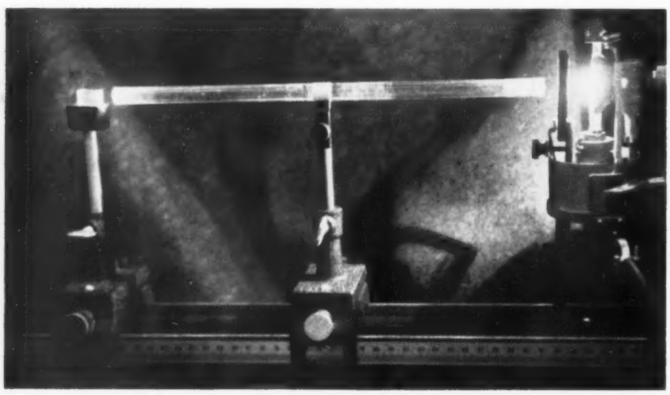
A crystal maser can be tuned over

a wide range by varying the magnetic field. In a ruby crystal, the spinning electrons are in chromium ions within the crystal lattice. The energy levels of the ion are also determined by interaction with the rest of the crystal lattice—the internal crystalline fields. R. C. Pastor of Hughes has shown that this interaction can be changed by putting the resonant ion of interest into different host crystals. Thus the maser frequency can also be varied by this method, called chemical tuning.

T. H. Maiman of Hughes has built ruby maser amplifiers in which the product of gain and bandwidth is over 100 mc, gain and bandwidth being traded, one for the other as desired.



Possibilities for a solid-state optical maser exist in the characteristics of ruby crystal, described in the chart above, and in the phenomenon shown in the photo below—light "pumping" a Laser. A large synthetic ruby crystal is on the left, illuminated by light transmitted through a quartz pipe, after the light from the lamp on the right is filtered by a red filter. The ruby glows throughout its body by emission of fluorescent R lines. A color photograph would show the red glow from the ruby; the light pipe would appear almost nonilluminated.



Gain-bandwidth products of the order of 1000 mc are obtained with double-cavity masers. The output power of a maser, for a given pumping power, is also severely affected by nonradiative transitions of excited ions from upper to lower levels. This is the normal process of thermal relaxation to the equilibrium condition, caused by interactions beween the ions and the crystal lattice due to its thermal agitation. The energy stored in the upper ion level will not be available as useful amplifier output if the ion gives up its energy to heat the crystal lattice. This competition between thermal relaxation and the rate at which ions can be pumped into the upper level makes many crystals unsuitable for maser use. The problem is greatly ameliorated by cooling the crystal. Dr. Maiman has succeeded, however, in getting maser action in ruby at a temperature as high as that of dry ice (195 K).

Many Uses in Space Probing

Solid-state maser amplifiers are being used in radars and radio telescopes, and because of their extreme sensitivity are being readied for space communication and detection applications. Such uses are possible because the system antennas are looking at the sky (low-temperature space) rather than at the warm earth, which radiates so much thermal noise it would "blind" the sensitive maser to the weak signals being detected. The maser can increase the number of available channels in a communication system, such as a global one using satellites in orbit as relays. By means of maser amplifiers, the range of radio telescopes, such as the one installed on a 50-ft parabolic antenna at the Naval Research Laboratory, has been greatly increased, making possible the exploration of a greater part of the universe than heretofore. At Hughes, the range of a typical radar has already been doubled, equal to what could have been achieved by increasing the transmitter power over 10 times. Further improvement is possible. At the Lincoln Laboratories a maser amplifier made possible the detection of radar echoes from the planet Venus; the closest distance of Venus to the earth is about 26 million miles. Of course, the maser receiver on earth can decrease transmitter power in satellites or planetoids.

One clear direction of maser research and development in the future is toward higher frequencies in the millimeter, infrared, and optical bands. Here, low-noise amplifiers, such as those using parametric methods, are not likely to achieve much practical

success because of the requirements for nonlinear elements and high-frequency pumping power. A maser, however, can be pumped by incoherent radiation. In addition, no pumping power whatever is required in the beam maser.

An optical maser is under development at Columbia Univ. by C. H. Townes and his associates. This uses potassium (or cesium) vapor and is pumped by the violet light from a separate potassium-vapor lamp. The potassium emits into a cavity made of two reflecting endplates in an optical interferometer arrangement instead of the usual microwave cavity. This allows the interferometer to select the proper mode or wave to couple to the emitting atoms in a way which would not be possible with an ordinary cavity of similarly large size; the latter would have too many modes of oscillation near the infrared frequency emitted by the potassium. Theoretical considerations indicate the possibility of maser action with this method, leading to output powers of the order of a milliwatt and a spectral width one-million times less than that from a vapor lamp. The interferometer would generate an infrared beam with a width of about 1 sec of arc—one so narrow and so coherent that, if transmitted to the moon, the amplitude of the signal there would be of the order of a lamp placed nearby. The possibilities here for space communication are exciting.

Iraser and Laser

It would be desirable to make an Iraser and Laser using solid-state methods, by techniques similar to those described above for potassium vapor. The problem, of course, resides in finding suitable materials. An illustration of the possibilities is shown in the figure on page 102 giving the energy-level diagram of ruby. The "green" and "blue" absorption bands (which cause ruby to appear red) can be populated by pumping with a powerful light source. The pumping can be done with a broad source because of the bands; and yet, ultimately, by radiationless transitions, the energy will be concentrated in the R levels. The two "red" (R-level) emission lines shown in the diagram can, in principle, be used for Laser action. The fluorescent R lines can easily be seen; relaxation times are good because the transitions from the R levels are partly forbidden, so that lifetimes of the order of milliseconds are obtained. The accompanying photograph shows a large, synthetic ruby illuminated by light transmitted through a quartz-light pipe and red filter. The crystal glows red due to the fluorescence of the R lines; this is not the same red as in viewing the crystal by reflected light. A black and white photograph cannot, of course, show the characteristics of the fluorescence fully.

If a very coherent microwave or infrared-maser source can be made bright enough, there might be a possibility to orbit it around the sun in a man-made planetoid while transmitting back to earth, and to see it with a high-resolution telescope when the transmitted beam passes near the sun. The beam would then be deviated by the sun's gravitational field through about 1.75 sec of arc, an amount *independent of its frequency* (diagram page 38). This would be caused by the nonEuclidean geometry of the space near the sun. The light beam has weight and follows a straight line, or geodesic path, in four-dimensional space-time according to the General Theory of Relativity. This prediction of Einstein has been roughly verified by photographing stars whose rays pass near the sun during a solar eclipse. Since the sun's brightness at

microwave or infrared frequencies is much less than for visible light, it might be possible to see an orbiting maser in daylight without an eclipse.

Since the optical spectral width of, for instance, a potassium Iraser is much less than that of a gas discharge, the effective temperature and brightness of an Iraser should be very much higher than that of the sun's surface. The use of a maser amplifier to detect the signal from the satellite could greatly aid in providing the needed sensitivity for this experiment. If such a verification of Einstein's theory could be made, it would greatly strengthen the support for General Relativity and the explanation of gravitation in terms of a nonEuclidean space-time geometry.

We can think of this experiment as measuring principally the spatial curvature caused by gravity, whereas the satellite clock experiment would measure the temporal curvature caused by gravity. That is, the first experiment depends largely on that component of the metric tensor which goes with the space coordinates, while the second depends on that component which goes with the time coordinate. If space-time were flat, these components would be unity. Because of the gravitational field, they depart slightly from unity —that is, space-time is "curved." This curvature is measured by these experiments, which thus supplement each other.

Planetoids May Be Heard

Planetoids for this experiment may not be too far off, since Pioneer V has been heard, at the time of writing, at distances of over two million miles and may eventually be heard up to 50 million miles away with ordinary transmitter powers of only 150 watts. The planetoid experiment requires transmission for only short periods during orbiting.

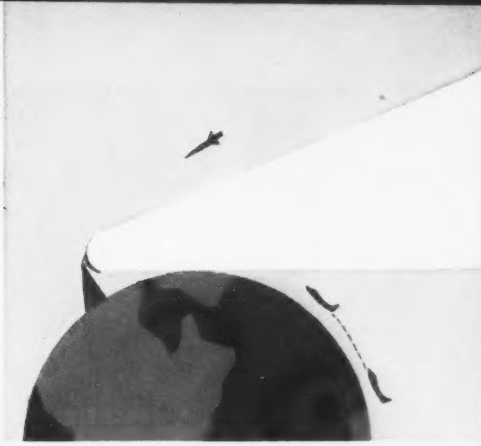
These examples indicate the possibilities of a quantum electronics far beyond the capabilities of free-electron devices. ♦♦

New Science Films Available

A new series of 10 educational films, "Horizons of Science," created by Educational Testing Service, Princeton, N. J., aided by NSF grants, is now available. Each of the films covers a specific science by showing a leading scientist in the field going about his work. Designed for use in schools, the films are being bought primarily under corporation and foundation sponsorship at a cost of $2000 for the complete set and then presented as a public service to school systems.

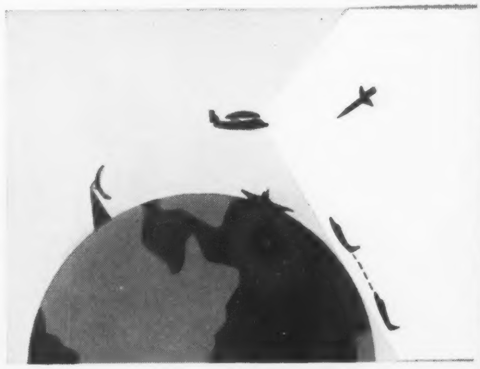

NAVY
GRUMMAN AIRCRAFT ENGINEERING CORPORATION

PEACE TAKES A LOT OF WATCHING!



Low-flying "enemy" aircraft or missiles are undetected by ground radar because, as the diagram shows, the range of ground-level radar extends no further than the horizon.

Detection range is increased appreciably when the radar detection equipment is airborne directly over the ground installation.



The scope and effectiveness of radar detection are extended dramatically with WF-2's operating off fast, mobile and far-ranging aircraft carriers at sea.

That's why the U. S. Navy will send eyes aloft to scan the seas and skies beyond our shores. The eyes, with this special kind of vision, are early warning aircraft. Many will be WF-2 "Tracers", produced for the Navy by Grumman.

WF-2's "see" via a saucer-shaped radome that houses super-sensitive, long-range electronic detection equipment. Operating from aircraft carriers far out at sea, "Tracers" patrol the extremities of our defense perimeter. And, detect the approach of aircraft or missiles that might invade the privacy of a nation's peace.

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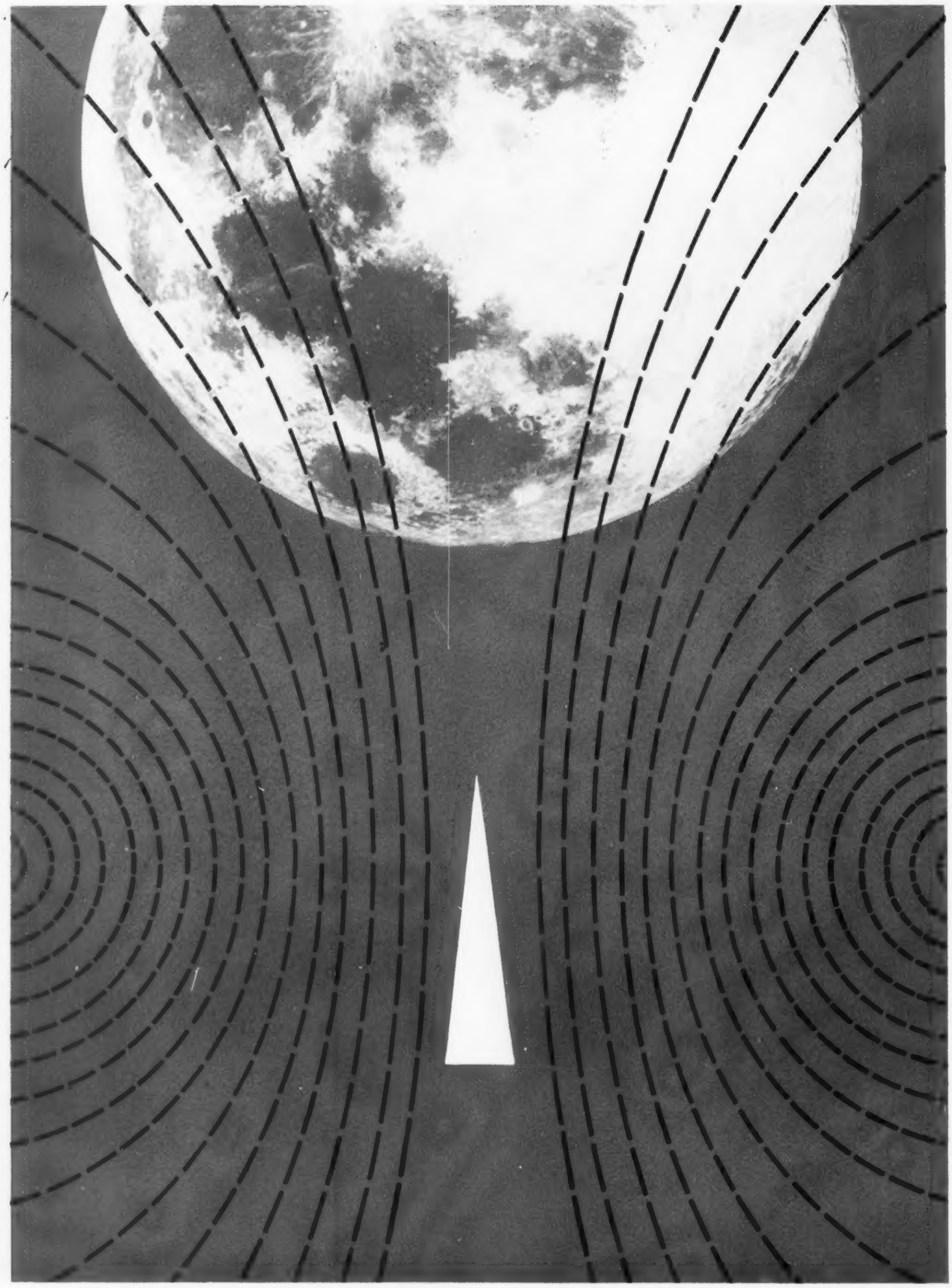


In print

Telemetering Systems by Perry A. Borden and W. J. Mayo-Wells, Reinhold Publishing Corp., New York, 1959, 320 pp., illustrated. $8.50.

Perry A. Borden and Jim Mayo-Wells are among the oldest pros in the telemetering field. "Telemetering Systems," which is a joint effort, is a well-organized book which surveys the field of telemetry and industrial telemetry applications. An abundance of diagrams, photographs, and system descriptions will be found between the covers and should prove interesting reading to the neophyte or nontelemetering specialist. An adequate bibliography will allow the more interested reader to go on into deeper literature describing telemetry activities.

From an engineering point of view, the book is slightly disappointing in its lack of technical content. However, it may prove to be a useful supplement to the highly technical book by Nichols and Rausch, "Radio Telemetry" published several years ago.

"Telemetering Systems" may certainly be recommended to the propulsion engineer, the industrialist, or the stress analyst who is interested in knowing what telemetry is and how it may help him in his work.

M. A. Lowy
Data-Control Systems, Inc.

Window in the Sky by Homer E. Newell Jr., McGraw-Hill, New York, 1959, 105 pp., illustrated. $2.75.

In these days of excitement about deep space and the nature of the planets and their atmospheres, the existence of our own atmosphere and its many interesting properties is sometimes forgotten by writers.

The atmosphere is the subject of this book of 105 pages. Dr. Newell, prolific author and distinguished scientist, has called the atmosphere the "window" through which we look to the sky. In 19 chapters, illustrated profusely with sketches, he shows that this window is not completely transparent to the radiations coming from space. The atmosphere has also various chemical and electrical and thermal properties that make it a most fascinating and fruitful subject for study.

The author begins by mentioning some of the unknowns in the atmosphere and things related to the atmosphere, such as the aurora borealis. He emphasizes that the sun is of course responsible for most of the atmospheric phenomena, such as winds, precipitation, clouds, and electrical events.

He goes on to discuss the beginnings of the earth's atmosphere and mentions several hypotheses on the origin of the atmosphere, among these being the occlusion of gases from a cooling, shrinking earth in its infancy. This presumes that volcanoes issued jets of hot gases consisting of carbon dioxide and oxygen, and perhaps hydrogen and nitrogen, into the region about the primeval earth. Newell is emphatic in claiming that oxygen was probably produced by photosynthesis and the dissociation of water vapor.

The author, dealing as he does with scientific terms continually, uses the metric system throughout. He is one of the small group of popular authors who recognizes the awkwardness of the American system for scientific measurements, and provides a table near the beginning of the book which converts metric units to the pound-foot system. However, since the book is obviously written for a lay audience or younger people, one wonders whether it would not have been better to use the American system throughout, thereby saving the reader the trouble of checking the table on each occasion.

After dealing with the various physical phenomena of the atmosphere, such as the heat capacity, temperature, atmospheric pressures, etc., the author gives one of the clearest explanations this reviewer has seen on the collision frequency and mean free path of molecules in the air. In these days of much talk of hypersonic flight and reentry heating, a simple explanation of molecular motion is in order and necessary.

In Chapter 11, there is a review of the causes and effects of winds and turbulence in the atmosphere, and in two pages Newell mentions the various wind velocities encountered by rocket testings at altitudes up to 80 miles or so. Surprisingly, no statement is made of the importance of jet streams to modern air transportation and aerology. Modern high-altitude, high-speed air travel is very much dependent on high-altitude winds above 25,000 ft, and the phrase "jet stream" is becoming well known. The author might also have mentioned some interesting atmospheric phenomena, such as that occasioned by the explosion of the volcano Krakatoa near the end of the last century. This fantastic phenomenon distributed steam and

dust particles around the earth in a matter of days so that the whole atmosphere was contaminated.

From Chapter 12 on, Newell treats the interesting area of electrical phenomena in the atmosphere, showing the interaction of the earth's magnetic field with charged particles from space and the effects of these charged particles on the upper regions of the atmosphere or ionosphere. A chapter on cosmic rays is included, although this is not strictly an area belonging to the atmosphere except in the *results* of the cosmic rays upon the atmosphere.

Much work has been done in the past century on atmospheric research, of course, by theoretical and practical scientists, including many balloonists who have risked life and limb to explore the atmosphere. Physicists such as Heaviside and McLennan have studied and analyzed electrical regions in the ionosphere. Surprisingly enough, not a word is said of most of these pioneers. Any book, particularly one catering to younger and fresher minds, should have in it something of the great achievements and enterprises that have led to our present knowledge. On the other hand, the author, obviously trying to keep the book small and simple, may have believed that the addition of historical data to each chapter would lengthen the book unnecessarily.

It is shown in the book that the atmosphere does not have a definite, sharp boundary but rather diffuses gradually outwards. The author mentions the earth's magnetic field and electrical currents in space and the radiation belt, although in a strict sense, these phenomena are separate from the atmosphere and could exist around a heavenly body such as the moon without an atmosphere. Newell raises the interesting question of whether there is a connection between the Van Allen radiation belt and the ionosphere. He does not give any theories and, indeed, considering the altitude of this radiation belt, that is, well over 400 miles above the earth, one doubts that there can be much of a relationship.

Chapter 17, on meteors, is, like the rest of the book, crisp and clear, and the reviewer has yet to see, in three pages, so good a description of the nature and characteristics of meteors and meteorites. The author points out that spacecraft designers of the future will have to face meteor erosion or collisions and must either sidestep this problem or design the space vehicle to counter it. Apparently, the book was not written in time to give some data on micrometeor density in space, as measured by U.S. and Russian satellites. The relationship between me-

teor entry into the atmosphere and hypersonic re-entry and heat-transfer problems might have thrown some light on the currently much debated question of re-entry. Also, the fact that meteor trails have been measured by radar by Millman in Canada might have added extra depth to this chapter.

The book ends fittingly with a chapter on the "Top of the Atmosphere" and Newell states that the sun's atmosphere, or its "corona," extends throughout the solar system. Its "temperature" in the vicinity of the earth is estimated to be 250,000 C. Unfortunately, he did not point out that this temperature is not the same as the temperature one measures with a thermometer on the earth's surface in the dense atmosphere. The untutored reader may have the impression that this temperature is the *total* temperature, as is understood from everyday experience.

A short epilogue gives a prophetic little message on man's opening of this "window" some day to escape. From some of Dr. Newell's recent statements on space-radiation hazards, however, men may not be in any hurry to "escape." A glossary of terms is very helpful and almost a must for the reader before beginning the book.

Brief, to the point, and breezy, and garnished with nice illustrations furnished by Gustav Schrotter, this is a useful book for the young would-be space scientist who may forget that the atmosphere is still very much with us.

Kurt R. Stehling
NASA

RECEIVED

Aircraft and Missile Design and Maintenance Handbook by Charles A. Overbey (The Macmillan Co., New York, N.Y., 369 pp., $9.75).

Astronomy of Stellar Energy and Decay (216 pp., $1.50); **Theory of Optics** (546 pp., $2.45); **Internal Constitution of the Stars** (407 pp., $2.25, Dover Publications, Inc., New York, N.Y.). Soft covers.

1959 Research Highlights of the National Bureau of Standards (Supt. of Documents, U.S. Govt. Printing Office, Washington 25, D.C., $0.55).

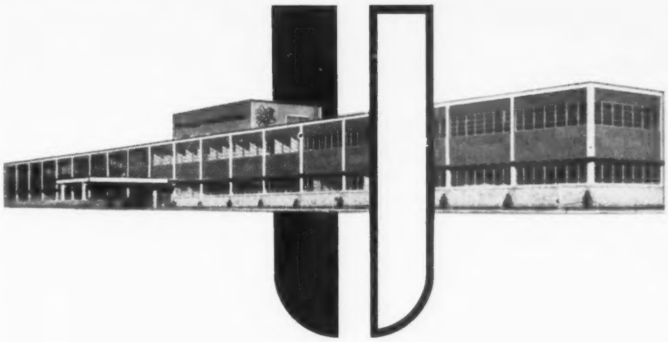
Proceedings of 1959 Aircraft Hydraulics Conference Vols. 1 & 2 (Vickers Inc., Detroit 32, Mich.). Soft cover.

Electronic Computers: Principles and Applications by T. E. Ivall (Philosophical Library, New York, N.Y., 263 pp., $15.).

First Book of Astronomy by Vivian Grey (Franklin Watts, Inc., New York, N.Y., 68 pp., $1.95.). For children.

Air Technical Dictionary: German-English, Edited by H. L. Darcy, et al. (Duell, Sloan & Pearce, Inc., New York, N.Y., 312 pp., $10).

Fundamentals of Stress Analysis by Albert Deyarmond and Albert Arslan (Aero Publishers, Inc., 2162 Sunset Blvd., Los Angeles 26, Calif., 256 pp., $5.75.)



Lunik III Photography

(CONTINUED FROM PAGE 29)

appearance of splotches, or "snow," indicates the presence of considerable noise when the picture was transmitted to the ground. Some of these splotches can be identified, since they occur only on individual frames of the pictures.

The released pictures are reported to be unretouched and yet, in the large-scale picture shown on page 28, the image of the moon differs appreciably from a circle. The reason for this is not known. By superimposing a large-scale version of the circular Lunik picture in the top left photo on page 29 upon the one on page 28, one finds there is an apparent compression of the upper half of this picture, thus indicating the probability that an error exists in reassembly of the line-scan data.

What sort of resolution was achieved in the Soviet moon pictures? Resolution is usually determined by photographing a standard target consisting of black and white stripes of decreasing width. The limiting resolution is defined as the narrowest width (called a line, and consisting of a black and white bar) at which the black and white bars can be distinguished, and it is usually expressed in lines-per-millimeter. Aerial photographers frequently speak of ground resolution as that distance on the ground which corresponds to the projected dimension of a single line at the limiting resolution of the camera system.

Estimating Resolution

When estimating the resolution of a picture which does not contain a resolution target, the photographer usually views an area containing high-contrast detail in an effort to find some spot with black and white stripes from which an estimate can be made. By this method, it is generally agreed, the ground resolution of the best moon pictures taken with astronomical telescopes is about 1 mile. At other times, the photographer will judge resolution on the basis of his experience or by comparison with pictures of known or controlled quality. This latter technique is preferable for determining the resolution of the Lunik III pictures, since most of the small dots are probably caused by noise in the communication link.

At top left of page 29 is a photo of the back of the moon, together with three pictures of the front of the moon reproduced at different resolutions. The unaided eye views the moon with a ground resolution of about 70 miles. This resolution is therefore included, together with ground resolutions of 30 and 10 miles to show the influence of resolution on surface appearance. By comparing pictures of this type with the Lunik III pictures, it is possible to estimate ground resolution of the Lunik III picture to be about 30 miles. Differences in surface texture are likely to have been caused by the use of different techniques in the reproduction process.

The pictures of the front side of the moon shown on page 29 were made by photographing simultaneously a low-contrast picture of the moon and a high-contrast resolution target. The resolution was varied by changing the scale during this copying. However, since it was not always possible to achieve the desired results, final control over the resolution was exercised by means of the focus in the enlarger. The final prints were all made on high-contrast paper so that they might, to some extent, resemble the Lunik pictures, which exhibited very few shades of gray.

What is significant is that the exciting first pictures of the hidden side of the moon have been taken. Al-

though their resolution is only about 30 miles, they have demonstrated the practicability of exploiting the space vehicle for astronomical research. The next step in lunar surface exploration will be to acquire pictures of better resolution under some favorable lighting conditions. When it is possible to obtain resolutions of better than one mile, photography of the front as well as the back side will be needed for more detailed study. These high-resolution pictures will be of far greater scientific importance than the early exploratory photographs in the study of the origin of the solar system and the history of the lunar surface.

Author's Note: The work on this paper and the writing thereof was completed in Washington, D.C. An independent analysis, using some different photos and other material, has been completed recently by two colleagues working in Santa Monica. It is referenced, and should be consulted.

References

Davies, Merton E., "Lunar Exploration by Photography from a Space Vehicle," *Proceedings of the Tenth International Astronautical Congress, London 1959*, Springer-Verlag, Wien, 1960.

Katz, A. and Burke, T. F., "On the Soviet Back-of-the-Moon Photographs—More Data, Photographs, and Speculation," The Rand Corporation, Paper P-1935, Feb. 10, 1960.

"The Moon's Hidden Side," U.S.S.R., vol. 39, no. 12, 1959. ♦♦

Complete Polaris, Minuteman Fuel Chamber Tests

Avco Corp.'s Lycoming Div. has completed an extensive program of hydro-tests of small-scale pressure vessels simulating full-scale Polaris and Minuteman fuel chambers. The burst-test program was designed to develop heat-treatment processes which would insure maximum strength for second- and third-stage Minuteman and second-stage Polaris chambers being developed by Lycoming for Aerojet.

Flight Simulation Equipment For NASA's Goddard Center

NASA's Goddard Space Flight Center, now under construction at Greenbelt, Md., will be equipped with a $400,000 omni-environmental test facility capable of simulating extreme temperature, altitude, acceleration, vibration, and shock. Being developed for NASA by MB Electronics, the new facility is expected to be at least partially complete by the end of 1960.

Nondestructive Testing Institute in West

A "Summer Institute on Nondestructive Testing," aimed at engineers, inspectors, and operators will be held by Sacramento State College, Sacramento, Calif., from Aug. 15–16. The fee for the two weeks of concentrated instruction will be $175. For further information, write Dr. G. N. Beaumariage Jr., SINT, Dept. of Engineering, Sacramento State College, 6000 Jay St., Sacramento 19, Calif.

Solid-State Transponder

(CONTINUED FROM PAGE 31)

Basically, the transponder would consist of a receiver to detect the radar pulses; a modulator to regenerate the pulse and delay it a known amount of time; and a transmitter to transmit the delayed pulse back to the radar set at greatly increased signal strength. The use of such a transponder would make the radar performance independent of target size, so that small second or third stages could be tracked at ranges of several thousand miles.

For a given radar set, tracking range on targets without any active tracking aids, the so-called "skin tracking" range depends on the size of the targets. The radar "illuminates" the target with its transmitter and then looks for the "reflection." Even with a powerful radar like Millstone Hill, the power reflected from a small target, such as a third-stage rocket, at ranges of 2000 miles, is only a few millionths of a watt. It can thus be seen that a beacon transponder which radiates a hundredth of a watt or more of power represents quite an improvement.

The transponder has the added advantage that the transmission is one-way. Hence the signal received at the radar set falls off as the square of the range. In the skin-tracking case, the same power must go both ways from the radar to the target and back to the radar again, so the signal falls off as the fourth power of the range.

It was clear that such a transponder was necessary if the Millstone radar was to participate successfully in the several different classes of missile test programs. A suitable beacon which could meet the size and weight requirements did not exist at that time. Hence an accelerated program to develop this type of tracking aid was undertaken at Lincoln Laboratory.

Semiconductor devices capable of producing the few milliwatts of UHF power needed were available in experimental quantities. Hence it appeared feasible to make a completely transistorized transponder. This would lead to a small light unit which could operate from self-contained batteries. Installation on the missile, and checkout, would be greatly simplified if the transponder were independent of the vehicle power supply.

A laboratory breadboard model of the transponder was built and electrically tested in about six weeks. While time did not permit environmental testing of the unit, it was installed in a missile early in July 1958. Operation of this unit became erratic while the rocket was on the launching pad. Although this particular test was operationally unsuccessful, an important point had been proved. A transponder using only semiconductor devices could be made to operate in the 450 mcps region at power and sensitivity levels that would extend the Millstone radar's range on small targets to about 10,000 miles. There was little doubt that a similar unit could be made to survive the missile/space environment.

The transponder development program continued at the laboratory, with several new approaches tried and tested. Some of these resulted in substantial improvements. High-frequency transistors became more readily available, and their operating efficiencies improved.

New Designs

A new receiver was developed consisting of a crystal mixer, a five-stage 30 mc IF amplifier and detector, and a crystal-controlled local oscillator which was multiplied four times, in frequency. New modulator designs which resulted in excellent delay and pulse-width stability were developed. A number of new transmitter designs were tried. The most successful of these consisted of a crystal-controlled oscillator which operated continuously, a buffer amplifier, two frequency doublers, and a final power amplifier. The buffer, doublers, and final amplifier were pulsed by the modulator. This combination gave more than enough output power and quite good frequency stability under extremes of temperature. All that remained was to package the system and stabilize its performance under the adverse conditions of temperature, shock, vibration, and power supply variations.

The last statement seems to indicate that development was complete. Such was not the case. It should be pointed out that this packaging phase was certainly difficult and probably the most expensive part of the development. Since Lincoln Laboratory was not equipped with the necessary environmental testing equipment, it was decided to complete the development outside the laboratory. A set of specifications was written based on our experience in and out of the laboratory.

Shortly after the specifications were written and approved, STL again approached Lincoln Laboratory for tracking assistance from Millstone on the Transit satellite program. Funded by the AF Ballistic Missile Division, a contract for final development and prototype production of the transponder was let to the Douglas Aircraft Co., prime contractor for the Transit vehicle. Douglas constructed the antenna and mounting hardware at its Tulsa, Okla., plant and subcontracted the transponder construction to Texas Instruments. This contract called for design, construction, and qualifying a transponder within 90 days, and production of several more in the ensuing few months.

Lincoln Laboratory maintained technical cognizance and final performance approval, as well as providing ground checkout equipment and personnel. The Lincoln specifications and breadboards were used as a basis for the design. Texas Instruments instituted a number of improvements which resulted in an excellent transponder design.

A block diagram of the final transponder is shown on page 30. The cavity filter reduces possible interaction between the transponder and other systems on the vehicle. The strip-line hybrid, a Texas Instruments' innovation, provides isolation between the transmitter and receiver and reduces the local oscillator radiation. The local oscillator chain contains a crystal oscillator operating in the 100-mc region followed by a buffer and a times-4 varactor multiplier. This chain produces a milliwatt or two of power in the 400-mc region.

The IF amplifier is built up of modules of an existing design using silicon tetrode transistors. The video amplifier and processing circuits are straightforward. R-C filters are used to discriminate against unwanted short pulses. Texas Instruments designed an improved timing and modulator circuit which is lighter than the original design and gives satisfactory timing accuracy.

The transmitter system consists of a crystal oscillator operating in the 110-mc region, a buffer, two doublers, and a final amplifier. This combination has delivered better than 20 mw of 440-mc power. The modulator consists of series switching transistors.

Power for the transponder is supplied by a set of rechargeable silver-

zinc batteries with a 40-hr lifetime. This life can be varied by using smaller or larger battery packs to suit particular applications.

The antenna system, developed by Douglas, is a turnstile array using four gamma-matched unipoles fed in quadrature. This type of antenna is used because the radiated polarization is linear when viewed from the side of the missile and changed to circular when viewed from the nose or tail aspects of the vehicle. The turnstile configuration is the closest approach to the ideal isotropic radiator which could be installed on the vehicle at a reasonable cost in size and weight.

The completed transponder, at top left, page 31, is in two packages. One, which contains all the RF Circuitry, is at the top of the photograph, while the video section, modulator, and battery pack are contained in the package shown in the lower portion of the picture. As shown, the transponder is mounted on the interface structure between the third stage and the payload.

The electrical performance of the transponder is more than adequate. Over-all interrogation threshold sensitivity is about minus 85 dbm. The power output is in excess of 10 mw, center frequency stability is equal to or better than $\pm$ 0.0015 percent, and range accuracy is 5 n.mi. or better under all specified environmental and battery conditions.

Gross weight of the complete transponder system including antennas is about 8 lb.

Range Extended

Use of this transponder extends the slant range of the Millstone Hill radar more than 10,000 n.mi. The transponder proved itself on the third stage of the Thor-Able vehicle used in the ill-fated Transit I launching on September 16, 1959. The Millstone Radar picked up strong transponder signals when the rocket passed over the radio horizon some 1000 miles distant and tracked the vehicle for about 14 min before it disappeared over the radio horizon again 1400 miles away. Not once did the radar lose track due to signal fade or interference.

One of these transponders is to be used with the Millstone radar for tracking the Tiros launch vehicle. While no other missions are planned for the immediate future, this type of transponder should see considerable service in the next few years. The combination of light-weight, very low-power requirements and capability of providing real-time tracking and orbit parameter determination at very long ranges will be valuable in many applications. ♦♦

Recoverable Space Probe

(CONTINUED FROM PAGE 35)

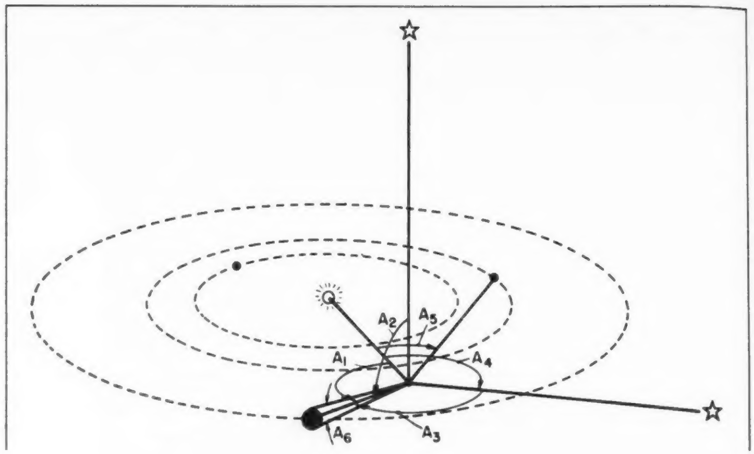
having an area of approximately 2 sq ft. These solar cells charge a 24-lb storage battery diagonally across from the electromechanical pod. The electrical power supply is coupled with the thermal-control system. The reflecting shutters, as shown in the illustration on page 34, are closed. As the vehicle moves further away from the sun, the shutters open, allowing more sunlight to fall on the solar cells. This arrangement provides a relatively constant temperature of 70 F in the vehicle and a nearly constant 6 watts from the solar cells—more than enough for the operation of this vehicle. The storage batteries can supply peak-power requirements. When the vehicle is quietly coasting with the energy-collecting face toward the sun, the power consumption in the clock, the computer, and the attitude-control system is only slightly more than 2 watts.

The array of dipoles on the energy-collecting face of the vehicle is used for sending a weekly message to earth. This message indicates the survival and condition of the vehicle, and could also contain intelligence on radiation, magnetic fields, and vehicle performance. This communication system has a range of approximately 350,000,000 miles when used with an 85-ft-diam collecting antenna on earth. It is operated at an information rate of approximately 3 bits per sec. The energy requirement for a weekly message indicating survival of the vehicle and some aspects of vehicle environmental conditions and performance is 200 watts for 20 sec. The radio equipment is installed in the battery pod.

The second antenna array is for the radar transponder used for the accurate prediction necessary for reliable recovery. The transponder has a range of approximately 100,000 miles and begins its operation 6 hr before the probe is scheduled to reach the earth.

The re-entry vehicle contains the camera, which has a single 6-in.-diam plate of very fine grained, slow film. The image of Mars is stored on this plate with a resolution of approximately 7 lines per mile. The re-entry vehicle protects its payload with an ablation heat shield and a structure which can withstand the hundreds of g's experienced in very steep re-entry trajectories with speeds up to 45,000 fps.

Measurement of Celestial Angles



The prospects for recovery are bolstered by the following conditions: Impact should occur within 200 miles and 5 min of the point and time specified before launch; pre-impact tracking combined with steep re-entry trajectories narrows this uncertainty in impact to several miles within the larger specified area; radio beacons and a high-intensity flashing light assure detection; and the re-entry vehicle, having half the density of sea water, should not sink.

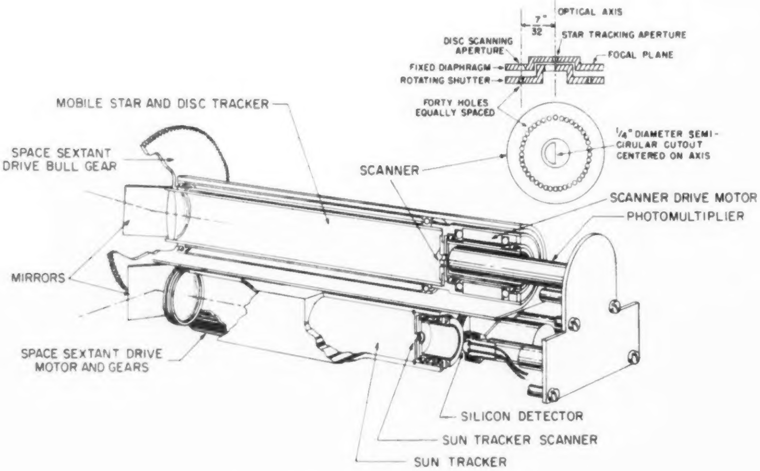
Fundamental Requirements

What criteria underlie the particular organization of the probe's electronic-electromechanical system?

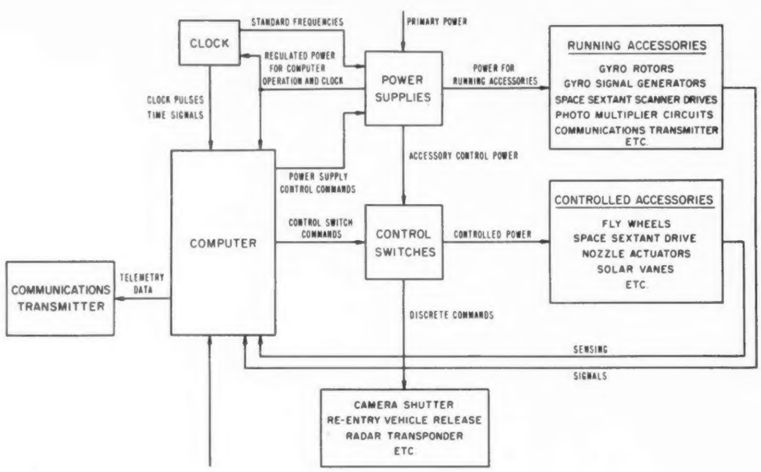
There are essentially six fundamental requirements on an interplanetary guidance and control system: (1) Functional ability to solve the specified navigation and control problem; (2) ability to operate at great range from the earth; (3) light weight and small size; (4) ability to operate within the available supply of energy; (5) long unattended operating life; and (6) great reliability.

It is clear that the complex operation of equipment at interplanetary ranges requires a fairly elaborate device in the probe for the control and sequencing of measurements, maneuvers, etc. This results from two factors. First, at ranges of the order of one astronomical unit, it requires some quarter of an hour for two-way communication between the probe and the earth. This time lag between the occurrence of a condition within the probe and the probe's reaction to this condition cannot be tolerated in any but the grossest and slowest of feedback loops. The communication system certainly cannot participate heavily, if at all, in even the relatively

Space Sextant



Space-Probe System Organization



slow measurement problem of determining six celestial angles within an interval of 1 or 2 hr. Thus, this complicated control sequence must be stored in the probe.

Second, there is a severe energy requirement for transmitting information from the probe to earth. Even at the range of one astronomical unit, it requires of the order of one joule for each bit of information transmitted to the earth. This results in a possible power limitation on the amount of navigation and control data sent from the probe to the earth at even this relatively close range. One can conclude from these factors that relatively complex interplanetary devices will be primarily automatic rather than radio controlled.

The need for light weight and small size in the equipment needs little interpretation. This tends to force the fulfillment of the functional requirement with devices which are as few and as simple as possible. A good illustration of this tendency is the combined use of the flywheels for attitude control and for the training of angle-measuring telescopes. This combination results in the elimination of extra degrees of freedom in the mechanism for measuring angles.

The guidance and control system can be made to operate within the available supply of energy by two possible approaches. First, the supply of energy can be made large by the use of an extensive solar-cell area or by the employment of some other large power supply. Second, the small solar-cell power supply, which can be instrumented with ease, can be made sufficient by the careful design of the system and its components with respect to energy requirements. The weight-size and reliability requirements make the second of these alternatives appear the more attractive. Therefore, in this preliminary design, low power-system and component operation was emphasized.

Unusually long unattended operating life is required of a system designed for a space mission of one to three years. This requirement in the described probe is not unreasonable, however, when one considers that most of the system will be completely dormant during more than 99.5 percent of its mission. This very low ratio of operating to dormant life can be realized by careful system design, and it nearly renders the term "operating life" synonymous to the term "shelf life."

The high level of reliability required in the probe's guidance and control system is achieved through a variety of design methods. First, the extremely low ratio of operating life to dormant life makes it unlikely that significant wear will occur through excessive use of the components. Second, the interplanetary guidance and control problem provides opportunity for the extravagant use of time in performing all operations in the probe at a relaxed pace. The probe contains no "tuned-up" high-speed servos or other high-performance devices, which are the usual cause for reliability difficulties. Third, by using nonlinear techniques in feedback loops and by using the abundance of time, the probe is designed so that its successful operation does not closely depend on the quantitative performance of any component.

Dominant Need

One dominant need appears when synthesizing and analyzing the operation and characteristics of the probe—the use of a highly specialized general-purpose digital computer within the probe. It begins to form when one considers the type of device necessary for the control and sequencing of measurements, maneuvers, etc. The measurement of one angle with the space sextant, for example, includes a sequence of operations, such as find the sun, energize the shutters of the space sextant, track the sun, set the space-sextant drive angle, search around the sun, track the located object, and, finally, precisely adjust the space-sextant drive angle. Each of these operations, in turn, involves a more detailed set of instructions. So, in nature, the operation of the guidance and control system is very susceptible to being organized into routines, subroutines, and sub-sub-routines used over and over again, like those in the program of a general-purpose computer.

	Time of fix and velocity correction	Uncertainty in fix miles rms	Expected velocity correction (ft/sec)	Error in knowledge of time (hr rms)
OUTBOUND	8 hr after launch	66	107	0.000
	0.6000 years after launch	9487	28	0.052
	1.200 years after launch	10.168	12	0.054
	2.050 years after launch	7250	23	0.080
	2.410 years after launch (4 days before arrival at Mars)	5992	224	0.065
	Passing Mars (2.4223 years after launch)		222	
	Total velocity correction outbound = 615 ft/sec; Miss distance at Mars = 203 miles; Velocity error at Mars = 126 ft/sec; Arrival time error = 0.797 hr			
INBOUND	8 hr after passing Mars	55	127	0.000
	0.6000 years after passing Mars	4065	130	0.049
	0.7960 years after passing Mars (1 day before return to earth)	2590	191	0.041
	Total velocity correction inbound = 448 ft/sec.; Miss at impact point = 80 miles; Total velocity correction for round trip = 1063 ft/sec; Impact time error = 0.164 hr			

Once the control and sequencing device is granted the type of storage and the logic needed to carry out its essential function, it requires only a small step to add an arithmetic capability and make the system completely self-contained and independent of communication with the earth. Further, this computer could have the capability of diagnosing malfunctions in the operation of the probe and of executing alternative procedures, such as resting for a while should difficulty be experienced in the middle of a set of measurements.

Necessity does force the use of an elaborate control device in the probe for the operation of mechanisms at great range from the earth. With slight extra expense, however, we reap the byproduct of being able to make the system completely self-contained by using a general-purpose computer as the probe's central organ of control. Another byproduct from the computer's ability to circumvent certain temporary and other system failures exists in the area of failure and performance telemetry. Since the sensing network of the computer naturally reaches out to all parts of the probe, it is quite natural for the computer to assemble a very compact "word" of performance and environmental data for telemetry transmission, with the saving of much energy.

The computer has a central position in the organization of the guidance and control system, as indicated in the diagram on page 118. It has direct communication with the various components of the probe through the numerous sensing and command input-output circuits. Studies indicate that its nonerasable storage of 4096 words is sufficient to contain the program to operate the probe and the necessary block of arithmetic data. This information is very efficiently and reliably stored by appropriately threading or not threading wires, each of which represents a bit, through magnetic cores, each of which represents a word. Thus, each 51-bit word of nonerasable storage requires only one core. The 256-word erasable storage is more conventional, using one core per bit. The use of cores for storage has the advantage of allowing various operating speeds for the computer, with the required power being roughly proportional to the speed of operation. The computer for the probe would use speeds of 20,000, 250, and 3 operations per sec, depending on the current workload. These operating speeds require powers of 50, 0.5, and 0.005 watts, respectively. The computer is capable of numerous discrete commands to the various external elements by setting relays, and

it is sensitive to numerous discrete inputs.

All of the other components have been tailored to work with the computer by accepting its discrete commands and giving it discrete signals. For example, the space sextant, shown in the illustration on page 116, is first turned on by a discrete command to the power supplies which energizes the shutters, the photomultipliers, and output circuits. To change the space-sextant drive angle, the drive motor is always commanded full-forward, off, or full-reverse. The approximate time required to make the desired change of angle (at 2 deg per sec full speed) is computed and the drive motor is appropriately energized. A sensor on the drive motor delivers to the computer a pulse of the appropriate sign for each 10 sec of arc change of the drive-output angle. This approximate process is reiterated several times until the drive angle is inched to the exact setting.

The signals from the sun and star trackers are also developed into discrete signals for presentation to the computer. In all precise tracking operations using the flywheels, the computer establishes a purposeful and stable null oscillation by operating on and delivering the discrete tracker signals to the flywheels as discrete commands. These oscillations have frequencies of approximately 1 cps and half-amplitudes of 5 sec of arc.

Dormant Mode of Operation

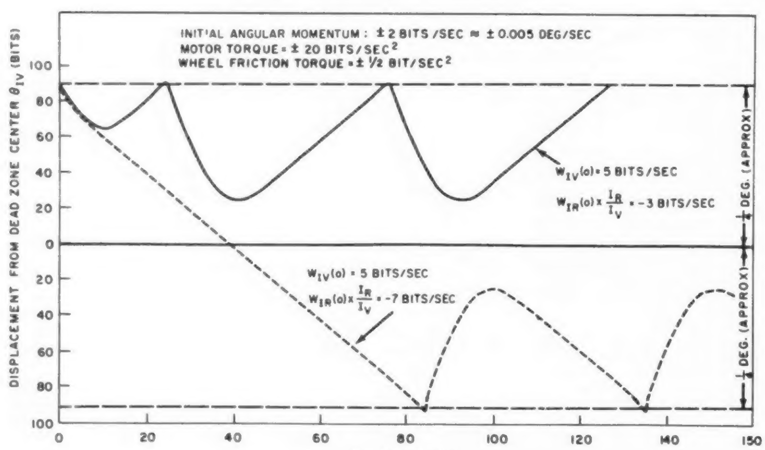
Finally, it is interesting to consider the dormant and normal mode of operation of the control system. During most of the trip the system only departs from this mode of operation for one-half hour per week to make a radio transmission and employ solar vanes. The other exceptions are an occasional hour-long measurement procedure for obtaining a navigational fix and a 40-min program for each 100 fps of velocity correction.

The dormant mode uses a pair of small wide-angle sun finders to indicate the direction of the sun with respect to the normally sunny face of the probe. These sun finders have a one-half degree dead zone purposely introduced between their plus and minus discrete output signals. When one of these signals occurs, the appropriate flywheel is energized for one-half second or until the signal vanishes, whichever is longer. The undamped nonlinear oscillation shown in the graph below, is the result. It can be seen that each flywheel motor is energized only 1 percent of the time, consuming a mere three-tenths of a watt average power. The table above shows the total power budget under these conditions.

Dormant Mode Power Budget (Watts)

x flywheel	0.30
y flywheel	0.30
Sun finders, dead-zone operation	0.30
Clock	1.50
Computer, standby speed	0.01
Leakage power for switches	0.15
Total	2.56
Available power from solar battery	6.00
Balance for charging storage battery	3.44

Dead Zone Attitude-Control Operation During Quiescent System Mode



As difficult as the problems of long-term reliability and of achieving the necessary operating life at first seem, it is my feeling that the requirement for perfection in conducting a complex interplanetary operation is the most difficult technical problem. This feeling results from observing that an interplanetary probe can operate in a very relaxed manner and that its equipment is not exercised excessively. At the same time, the probe is a complicated device. The program in the computer must operate the probe on its journey relying on the accuracy of the analysis and the execution of the relationship between the computer, the components, and the communication channel if one is extensively used. All of this work must be carried out impeccably without error in sign, wiring, or placement and interpretation of data. Yet, there is no really complete method for checking the system out without actual spaceflight. ♦♦

Sperry Successfully Uses "Gyro-Electric Plasma"

Sperry Gyroscope Co. engineers have successfully employed a fourth state of matter known as "gyro-electric plasma" to form a practical electronic circuit. A circuit formed by the plasma has been made to operate as an electronic oscillator to generate radar energy at extremely high frequencies.

The plasma was formed by aiming a slim beam of electrons through rarefied hydrogen gas contained in an electromagnetic envelope. The beam electrons strike the hydrogen atoms with sufficient force to knock them apart and create a plasma of charged particles of hydrogen atoms and electrons.

The project so far has generated radar energy at frequencies ranging from 700 to 2000 million cps, and redesign of the apparatus is expected to result in the generation of frequencies more than 100 times higher, a range approaching infrared waves.

JPL Adds Second 85-Ft-Diam Tracking Antenna to Facilities

JPL tracking facilities will be expanded in the near future through addition of a second 85-ft-diam tracking antenna near Goldstone Lake in the Mojave Desert in California. The antenna, a Type LB azimuth elevation model, is being built by Blaw-Knox, which installed JPL's first 85-ft-diam antenna in 1958.

Space Age Materials

(CONTINUED FROM PAGE 41)

another set of discrete levels which may be introduced in the forbidden energy gap. Such levels occur in germanium from Group III impurities with only three electrons for the bonding scheme. Group III impurities cause discrete levels into which electrons may be excited much more easily than into the conduction band. Such levels are known as "acceptors"; and when an electron is excited into one of them, it leaves a hole behind in the valence band that makes the crystal conductive.

Actually, these descriptions are oversimplified. Conduction in semiconductors is a many-body problem governed by statistical mechanics. In a pure semiconductor (one without acceptor or donor levels) the number of carriers available for conduction at any absolute temperature T is given by an approximate expression $N = N_o \exp(-E_g/2kT)$, where N_o is related to the number of levels available in the conduction band and k is Boltzmann's constant when the effective mass of electrons and holes is the same. Similarly, the number of carriers available in impure or extrinsic semiconductors is an exponential expression in temperature and E_D or E_A.

The conductivity (σ) in semiconductors is related to the number of carriers present for conduction by this expression: $\sigma = n_e\, e\, \mu_e + n_p\, e\, \mu_p$, where n_e and n_p are the number of electrons in the conduction band and the number of holes in the valence band, respectively, and μ_e and μ_p are the electron and the hole mobility. The n's have the exponential temperature dependence of the first equation previously presented and the mobility of a carrier is defined as the velocity in an electric field which a carrier acquires per unit field between scattering interactions with atoms in lattice sites. Mobility has a comparatively weak temperature dependence in most semiconductors, so that the conductivity is essentially an exponential in temperature.

The velocity a carrier acquires depends upon the distance it travels between scattering interactions. The diffusion length, an important semiconductor parameter, is a measure of this distance. Both the diffusion length and the mobility depend very markedly upon crystal perfection. Because of this, and for certain other pertinent reasons, polycrystalline samples are unsuitable for most semiconductor applications. Much effort and study, therefore, has gone into producing good single crystals free of dislocations and other imperfections.

Semiconductors which have more donor levels than acceptor levels—so that the first term of the equation given for conductivity—are called n-type semiconductors. When the second term dominates they are called p-type semiconductors. Most intrinsic semiconductors are n-type, since n_e and n_p are equal and μ_e is greater than μ_p in most semiconductors.

One other important aspect of semiconductors is the p-n junction. Such a junction results when n-type and p-type regions exist in the same crystal. Under equilibrium conditions, electrons have moved across the junction into the p-type region and holes have done the opposite, so that a barrier exists to further nonequilibrium motion. When the n-region is biased externally negative, more current will flow across the junction; but when it is positive with respect to the p-region, it becomes very difficult for charge to transfer across the junction. A p-n junction then is a rectifier.

The foregoing has been concerned mostly with conditions which exist in semiconductors at equilibrium. There are, however, some nonequilibrium conditions and parameters worth a moment. We have talked of thermal excitation of carriers, but it is possible to excite carriers into the conduction band by other means, i.e., by the absorption of radiant energy. When a photon with energy greater than E_g is absorbed, an electron is excited across the forbidden region and the resulting electron-hole pair becomes available for conduction.

Under the proper illumination, then, a new equilibrium condition with larger numbers of carriers is established, and the conductivity of the sample goes up, sometimes by many orders of magnitude. If the light is suddenly removed, however, it takes a finite period of time for the original equilibrium to be re-established. Actually, recombination has been going on all the time, but new carrriers are being generated all the time to establish equilibrium.

The time required to re-establish equilibrium is measured by a parameter known as "carrier lifetime." Nonequilibrium is established momentarily across a p-n junction when either holes are injected into a n-region or when electrons are injected into a p-region. The time required to re-establish equilibrium after the proper bias is removed is the minority carrier lifetime. It is easy to see, then, that diffusion length is related to mobility and lifetime, since the distance a carrier travels and the velocity it acquires are related to the time that it exists.

With these semiconductor fundamentals in mind, let us now examine

jobs required of semiconductor devices and some of the limitations of present materials and devices.

Solid-state diodes and transistors are today common and well known. These devices have the restrictions common to most semiconductors. One is temperature, either the ambient in which they must operate or the self-heating that occurs during use.

At a temperature low enough that few intrinsic hole-electron pairs are being excited, but high enough that most of the donors and acceptors are ionized, the number of donors controls the conductivity in the n-region and the number of acceptors determines the conductivity in the p-region. As the temperature increases, however, more and more electrons are excited into the conduction band, until finally these electrons and the resulting holes dominate the conductivity and the p- and n-regions lose their identity. In fact, the semiconductor becomes metal-like in its conductivity.

This is known as the intrinsic range of temperature; and a glance at the first equation on page 121 shows that the temperature at which a particular material becomes intrinsic is determined by E_g. Silicon with a band gap of about 1.1 electron volts (ev) will retain its semiconducting properties at a higher temperature than germanium, which has a band gap of only about 0.7 ev. Much of the interest in compound semiconductors stems from the large energy gaps of many of these materials. Silicon carbide has a band gap of about 2.4 ev; GaP, AlP, AlAs all have band gaps in excess of 2 ev.

Other Problems

A transistor consisting of three or more regions (usually p-n-p or n-p-n) with two p-n junctions has certain other problems of a fundamental nature. For one thing, the transit time of the minority carriers across the middle (base) region of the transistor controls the upper frequency at which it may operate. This transit time is related, among other things, to the mobility of the minority carriers in this region. Again the compound semiconductors, particularly the Groups III and V compounds, seem to hold the ultimate answer. Some of these compounds have mobilities of an order of magnitude or more larger than germanium. Mobility and diffusion length are also important in solar cells, which are essentially diodes with p-n junctions near one surface, so that the carriers which result from optical absorption are within a diffusion length of the junction. This allows one of the carriers to be collected cross the junc-

tion, and the device becomes a photovoltaic cell.

The paddlewheel satellite with its hundreds of silicon photovoltaic solar cells is familiar to most readers of the daily newspaper. These silicon cells have an efficiency of conversion in the range of 12 percent. Simple theoretical treatments have shown that the maximum efficiency one can expect from single-material solar cells is in the 20 to 30 percent range, and that the material which will give the maximum has a band gap of about 1 ev or slightly higher, because the peak of the solar-radiation spectrum falls in this energy range. Silicon falls near this ideal material. It has the serious limitation, however, of becoming intrinsic just below 200 C.

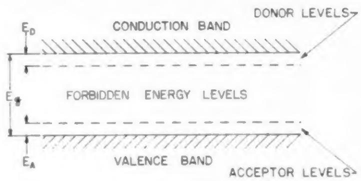
A great deal of work is being done on other materials whose energy gaps fall just above silicon in an attempt to extend the temperature range. These materials include InP at 1.25 ev, GaAs at 1.35 ev, and CdTe at 1.45 ev. In addition, research is being done on alloys of Groups III and V compounds for this application. This work is aimed at uniformly changing band gaps, so that a larger portion of the sun's spectrum is used. For the same reason, research is being pursued on stacks of solar cells, each of the bottom ones having a smaller band gap than the one immediately above it.

Most of the detection functions using solid-state devices rely upon the photoconductive response of a semiconductor crystal. Photoconductivity can be defined as simply the change in conductivity of a material due to absorption of electromagnetic radiation. The mechanism of photoconductivity can be explained descriptively on the basis of the diagram here at right. In a pure semiconductor, all radiation whose energy is less than E_g will pass through the semiconductor. But when photons of energy greater than E_g are absorbed, they will excite electrons into the conduction band. The sensitivity of the photoconductor will be determined by the number of carriers already present in the conduction band. The relative change in current ($\Delta I/I$) under illumination is made as large as possible by reducing the number of initial carriers present. Thus the most sensitive photoconductors are actually insulators in the dark or nearly so.

This makes the band gap E_g an important parameter in photoconductors, because in the exponential of the first equation on page 121 we desire to keep E_g large so that at ordinary temperatures the value of the exponential, and hence the value of the thermally excited carriers N, will be very small. Cadmium sulphide, which is probably the classic photoconductive insulator, has a band gap of 2.4 ev. Since E_g equals the lowest-energy photon absorbed in this process, the band gap also determines the highest wavelength radiation which will be absorbed. We speak of this highest wavelength as the "absorption edge."

The table on page 41 shows the relationship between these parameters for many of today's semiconductors. For detectors, however, one must compromise these two requirements according to the radiation it is desirable

Band Scheme of Semiconductors



to detect. Pure CdS, which absorbs everything below about 5000 Å would not be useful in the detection of infrared radiation. Both germanium and silicon, with much smaller band gaps, can be used in the very near-infrared (1 or 2 microns and below). But to detect radiation in the far-infrared, other materials must be used. InSb with a band gap of 0.18 ev is used for radiation slightly longer than that detectable with germanium and silicon. HgSe and HgTe with band gaps of 0.16 ev and 0.08 ev, respectively, extend the range even more. These last three materials, however, have the disadvantage that the band gap is so small that at room temperature many carriers are thermally excited into the conduction band.

To make the sensitivity great enough to use, then, these materials must be cooled to liquid-nitrogen temperature or below. InSb is also used in the so-called PEM detector, which makes use of the interaction of a magnetic field and the carriers excited by incident radiation. This device also must be cooled.

A technique developed recently to produce detection material for the far-infrared is to dope germanium with gold or zinc. Such detectors require cooling to a very low temperature, and their response mechanism is somewhat more complex than what has been described.

Another of the many interesting effects in semiconductors which is getting a great deal of attention these days is thermoelectricity. The Peltier and Seebeck effects were discovered more than a century ago. It was discovered that when a current is forced to flow in a circuit which contains two junctions of dissimilar metals one junction gets warm and one get cold. Conversely, it is known that if one heats one of the junctions and cools the other an electric current will flow in the circuit. The possibilities for using phenomena for heavy pumping and power generation, respectively, has long been recognized; but only with advances in semiconductor technology has it been possible to hope that such systems will become economically feasible.

The material requirements for thermoelectric cooling and for thermoelectric generation are somewhat different, i.e., generators must be made from materials which will withstand high temperatures. But there are more similarities in requirements, so we shall deal here with generation. It can be shown that the efficiency, η, of a thermoelectric generator is given by the expression $\eta = 1/2(T_1 - T_0)/[T_1 + 2/Z - 1/4(T_1 - T_0)]$, where T_1 and T_0 are the temperatures of the hot and cold junctions, respectively, and Z is a marterial parameter called the figure of merit, given by $Z = \alpha^2/(k_1\rho_1 + k_2\rho_2)^2$, where α is the thermoelectric power, k is the thermal conductivity, and ρ is the electrical resistivity. The subscripts refer to the two arms of the couple, and the expression reduces for a single material ($k_1 = k_2$ and $\rho_1 = \rho_2$) to $Z = \alpha^2/k\rho$.

For most metals the thermoelectric power is small, of the order of 10^{-6} volts per K, and the product $k\rho$ is of the order of the theoretical value, $2.5 \times 10^{-8}T$, where T is the average temperature of the element. For an average temperature of 500 K (element operating between 700 and 300 K), the figure of merit is approximately 8.2×10^{-6} and the efficiency η becomes 0.085 percent. A. F. Ioffe gives the best value for metals as Bi-Sb between 450 and 300 K with an efficiency of 3.1 percent.

In semiconductors, Z can be larger than 10^{-3} and the efficiency can approach 10 percent or higher.

Research Aim

Most of the research now being conducted is aimed at improving the value of Z in existing materials and searching for material with a higher figure of merit. In semiconductors, an optimum value of the α^2/ρ ratio may be attained by proper addition of donors and acceptors. The thermal conductivity should be as low as possible. Ioffe led the way in isoelectronic doping to reduce thermal conductivity. Isoelectronic doping is the addition of a material which lies in the same group

of the periodic table as one of the elements of the thermoelectric compound, i.e., selenium doping of Bi_2Te_3. This is possible since the thermal conductivity has two parts: The electron contribution, which represents the energy by the electrons, and the phonon contribution, which represents the energy transferred by the lattice. By isoelectronic doping, the lattice regularity can be disturbed and the latter contribution can be decreased.

At present, Bi_2Te_3 appears to be the best material for heat pumping applications where the temperature of the hot junction is not too high. Snap III, a generation device, which uses the decay of radioactive isotopes as the heat source, uses PbTe as the conversion units. GeTe, among others, has attracted much attention recently, but the low efficiencies still leave something to be desired. A great deal of research is in progress in this area, and there is good reason to believe that an improvement in materials will be worthwhile.

The requirements for power in satellite vehicles and space probes, manned or unmanned, will increase as instrumentation and over-all sophistication becomes more advanced. Thus far, only two means have been used to power the electronics of satellite vehicles—self-contained batteries and silicon solar cells. Another method which may become important is the heat engine, and the simplest possible heat engine is a thermoelectric generator.

A thermoelectric generator for space vehicles which uses solar energy as the prime source would consist of a lightweight mirror to concentrate the solar energy onto a thermoelectric module. It is instructive to consider the size and weight of a unit which can deliver, for example, 100 watts. Using materials available today, such as were used in Snap III, the weight of the thermoelectric materials alone amounts to about 1.5 lb, assuming that the length of each element is $^1/_4$ inch. The mirror would be required to maintain a temperature of 500 C at the hot junction, while the cold junction should be no hotter than 100 C. The surface area of the generator itself would be about 25 sq in. By comparison, a battery of silicon solar cells required to furnish 100 watts would weigh 0.5 lb and have a surface area of 13 $^1/_2$ sq ft.

Thus, both the thermoelectric generator and the silicon solar cells have their advantages and disadvantages. The thermoelectric generator weighs about three times as much as the solar-cell battery, but the area of the solar-cell battery exceeds that of the thermoelectric generator by a factor of

about 80. As the quality of thermoelectric materials is improved, the weight of a thermoelectric generator will approach that of a battery of solar cells.

But the sun is not the only possible prime source of power in spaceflight. In an unmanned vehicle, a nuclear reactor could be the prime source; and since no shielding would be required, the reactor could be very light. In this case, a thermoelectric generator could be advantageously used to convert heat from the reactor to electricity. For power conversion, thermionic is of as much interest as thermoelectric conversion. However, thermionic devices don't operate well in the lower temperature regions, and there is speculation that the ultimate device will be a combination of thermoelectric and thermionic generators.

Solid-state masers form another field of growing work with semiconductor materials, such as ruby. Harold Lyons discusses current work on various forms of the mass on page 38.

Low-temperature research is another field becoming more and more important in electronics. The last 10 years have witnessed an extraordinary growth of interest in basic research at temperatures below 20 K, as well as an equally rapid dissemination of low-temperature technology to fields remote from pure research—to computer design and missile propulsion, to name but two. The reasons for this sudden growth of interest are not hard to discover. Of prime importance, perhaps, is the circumstance that nature has provided an abundance of physical systems having energy levels separated by 10^{-3} ev or less. The equilibrium populations of these energy levels are governed by various classical and quantum mechanical distributions containing the factor exp (E/kT). Therefore, the many observable properties depending upon population will be changing rapidly at the very lowest temperatures, where an increase of 20 K can be an order of magnitude change in T. Notable among such systems are the paramagnetic salts, currently under intensive investigation in most of the world's major solid-state laboratories. Application of these salts to parametric oscillation and amplification is already well established, and future applications promise to be equally fruitful.

Of scarcely less importance is the circumstance that only at low temperatures do quantum-mechanical phenomena manifest themselves on a macroscopic scale. The superfluidity of liquid Helium II and the superconductivity of various pure metals and alloys have long occupied the attention of theoretical physicists, by reason of their conspicuous resistance to integration within molecular theory. On a classical basis, such "quantum liquids" should not exist at all. Ordinary quantum mechanics is for the most part powerless to analyze them; it is only when we include the effects of long-range ordering of momentum that these liquids begin to become understandable. In this manner a workable theory of superconductivity has at last been constructed. Many of its implications, however, remain to be explored, particularly those which suggest profound and intimate similarity to other cooperative phenomena in solids, such as ferromagnetism. The still more baffling problem of superfluidity appears to be yielding slowly to the combined efforts of theoreticians, as they gradually master the formidable problems of many-body mechanics, and experimenters, as they study the hydrodynamics and energy spectra of the He^3-He^4 mixtures.

Finally, it should be remarked that the techniques of the cryogenic laboratory are finding increasingly widespread application outside the field of physics. Electrical engineers, for instance, are on the verge of creating a wholly new breed of electronic computer—faster, smaller, and lighter than any now in existence—based on the London and Pippard equations for the electrodynamics of superconductors. It appears, in short, that we are about to witness the emergence of cryogenics as an applied science of the first importance.

Materials technology, however, is still in its infancy and new techniques and new devices are constantly being developed. Moreover, in space and airborne applications of electronics, we must constantly face the problem of weight and volume. Solid-state devices have from the start lent themselves well to miniaturization. The development of printed circuits, the miniaturization of components, and the microminiaturization of circuits pioneered by scientists at the Diamond Ordnance Fuze Laboratories have all been steps along the trail to less weight and less volume. But it has been said that with payload limitations of the foreseeable future reductions in size and weight must be at least 100 times better.

This has led to a revolution in the thinking and philosophy of circuit design, and the result has been a far-reaching research effort in molecular electronics.

This research aims at removing the circuit designer from a maze of building blocks which current devices represent. In the future he will think in terms of circuit functions performed in one building block, and the result will be smaller and lighter systems.

Almost without exception, the stumbling block to improved devices has been materials; and with the coming of microminiaturization and the performance of many circuit functions in one small building block, the materials problem has become more acute. Consequently, the search for new electronic materials is leading into many areas heretofore unexplored—into the Groups II–VI and III–V compounds containing three or more elements, into organic materials, into the oxides, and into the alkali halides.

Today we are on the threshold of an era in which it will be possible to truly specify materials for a particular function and have the molecular electronic engineers fabricate it to those specifications. But while research in materials technology is growing, it needs to proceed at a much faster pace if it is to keep up with our needs.

Suggested Additional Reading

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Television Cameras

(CONTINUED FROM PAGE 37)

under its everpresent cloud blanket. In addition, landing remotely controlled robots on the moon will bring, through the remote vision of the television camera, closeups of lunar surface materials.

These are some of the many scientific applications for which the television camera adapted for space may be used. Cameras may also be used to accumulate technical engineering data by monitoring critical instrumentation or rocket operations, making it possible to control more accurately rocket burning and stage separation from the ground.

A television camera for space must conform with many rigid requirements not demanded of the more familiar studio camera. In the first place, because a battery of cameramen, video men, lighting technicians, and program directors will not be present, the space television camera must operate unattended and without benefit of manual readjustment. Secondly, it must survive the high-vibrational shock associated with launching and must oper-

ate in the environment of space, which includes considerable temperature variations and an absence of atmospheric conditions. This requires that its materials be stable in a vacuum, its thermal design be tolerant of the lack of convective cooling, and that all of its moving parts be lubricated with materials having low-vapor pressure. In addition, the high level of radiation in outer space must not be allowed to cause cumulative adverse effects upon the operation of the camera. Power and weight, always restricting in space vehicles, must be held to a bare minimum.

These design restrictions, while severe, are still within the realm of practicality. The selection of an image sensor which is least susceptible to environmental parameters is a major and significant step in reaching the design solution.

The vidicon camera represents a significant advance in sensor design. Vidicons have now been developed for space applications. These are rugged, have relatively wide temperature limits, and have photoconductors especially tailored for slow-scan operation. These sensors, moreover, are insensitive to radiation, and thus do not need lead shielding.

Techniques Used

The use of transistors, printed circuits, modular construction, and bandwidth-conservation techniques, all lend themselves to the solution of reliability, power, and weight-saving problems. A camera chain, including synchronizing generators, has been built using only 80 sq in. of printed board area. The use of miniaturized components and the design of circuits to eliminate the need for large, heavy elements have made it possible to build this camera, including optics, to weigh less than $4^1/_2$ lb. With power saving an essential consideration, minimum-current transistor circuits have been designed, keeping in mind that reliability is of paramount importance. The incompatibility of these two requirements necessitates certain compromises. Optimum reliability has been achieved by using negative feedback in all critical circuitry and Zener diodes, for voltage regulation and circuit isolation. Using the above techniques, reliable operation has been attained while restricting the required camera power to less than 8 watts from a single 25-volt, DC supply. This is approximately the amount of power required to operate an electric shaver.

A more significant contribution to over-all system power drain is associated with transmitting the television picture over the long path lengths to the earth. This power and range, translated into signal-to-noise ratio at the receiver, is dependent upon the rate of delivering information, or signal bandwidth. The rate of information delivery may be reduced by a very large factor by slowing the TV scanning rate. The graph on page 36 shows the relationship of resolution and frametime in bandwidth determination. Further power reduction is achieved by eliminating redundancy; that is, by transmitting a given picture once and not sending a new picture until the scene has changed sufficiently to require it.

For example, in RCA cameras designed for space exploration, the picture frametime has been increased from 1/30 sec, common to commercial television, to 2 sec. This means that the bandwidth, and hence, the required transmitter power required to radiate this picture information, is reduced by a factor of 60. The price paid for this bandwidth reduction is that only slowly changing scenes may be viewed successfully by the camera. This is not an untenable restriction, however, for while the vehicle may be hurling through space at several miles per second, the actual rate of change of scene information in most space pictures is relatively slow.

The stability of the vehicle is an im-

Pilot in space suit entering McDonnell mockup of Project Mercury space capsule.

portant factor in these considerations. If the vehicle is spinning, a blurred image will result. To solve this problem, a shutter is used and the scene is immobilized in a manner similar to that used in still photography employing film. The storage capabilities of the vidicon's photoconductive surface allow short exposures to be made and scanned in the 2-sec frametime. For spin rates of 10-to-20 revolutions per min, a shutter time of approximately 1 millisec is satisfactory for a 500-line picture. If a slower spin rate or attitude stabilization is employed in the vehicle, shutter times of more than 1/100 sec would be practical, permitting operation with less light.

Usefulness Measured

The usefulness of the television camera can be best measured in terms of the dimensions in the scene it is capable of resolving and the minimum illumination which is required for an exposure. The scene detail is established as a factor indicating the best resolution of the photosensor and the selected focal length of the optical system. The half-inch vidicon has a resolution of 35 optical lines per millimeter on axis. The relationship which will yield scene resolution is expressed by the equation $G_R = S/300\ R$, where S is the scale factor, equal to the ratio of altitude to focal length, and R is the sensor resolution in optical lines per millimeter. G_R is the desired ground, or scene, resolution.

With reference to the minimum required scene brightness, typical vidicon operation will permit the following operating conditions: With 0.03 ft-candle-sec impinging on the photoconductor through the lens, an image bright enough to produce a good picture on the television screen will result. With an effective lens aperture ratio of $f/2$ and a 1-millisec exposure, a scene illuminance of 480-ft-lamberts would be required. (Special vidicons capable of 0.01 ft-candle-sec have been built.) Photography is then limited to times when the position of the satellite with respect to the sun and the scene is favorable and exceeds this minimum value. Larger payload capacity will permit the use of the image orthicon and other television sensors which possess several thousand times this sensitivity.

Within these limitations and design criteria, a number of cameras have been designed. The versatility of these designs is important, since, with slight changes in scanning rates, system bandwidth, focal length, effective aperture ratio, and spectral response of the sensor, all of the applications previously described can be realized. Future improvement lies in the direction of developing sensors and associated optics with increased resolution and sensitivity and communications systems with increased information-rate capacity.

The Tiros meteorological satellite cameras, developed under contract with the U.S. Army Signal Corps for NASA, were designed along the lines just described. These cameras, employing half-inch, red-sensitive vidicons produce a series of still photographs depicting the cloud cover over a large area of the earth; the photo on page 37 shows a half-inch vidicon. This design required a number of special features, one of which was an electromagnetic shutter capable of making exposures of 1-millisec for many thousand operations without failure. In addition to its high speed, its travel across the image plane is required to be quite linear, to eliminate extraneous shading.

The photo on page 37 shows the complete Tiros camera unit. It is equipped with a wide-angle lens for viewing the large expanse of the earth necessary to present the cloud patterns useful to meteorologists. The operation of the cameras in the meteorological satellite system will be described in a forthcoming article in *Astronautics*.

The recent pictures the Russians took of the back side of the moon using film technique represent the type of mission which is readily carried out by television. Under a contract to the Jet Propulsion Laboratory, a very lightweight television camera of the type just described was built for such a moon probe. This payload was not launched because of a change in planning, but the development and testing of the camera proved the feasibility of building a vidicon camera for this kind of exploratory mission.

The concept was to send a probe out past the moon with the television camera taking a backward look at the moon's opposite side. The resulting picture would have been transmitted while the vehicle continued to travel out into space. The principal system problem was the retrieval of the gathered information with a minimum expenditure of power, and consequently, of weight.

Other lunar trajectories can be designed for a near miss of the moon with the return leg of the trajectory closer to the earth, within more reasonable communication distances. The alternative to this return trajectory is the reduction of bandwidth still further to decrease the additional power required to span by radio transmission the distances to the moon and beyond. Bandwidth can be reduced by another order of magnitude with a magnetic-tape recorder. A tape recorder is capable of bandwidth compression by drastically reducing the playback speed. This solution to the problem of conserving the power allocated for communications is presently realizable.

In the JPL camera design shown on page 37, low weight and power consumptions were the primary design requirements. These requirements of economy are especially important in equipment destined to leave the earth's gravitational field under the power of expensive rocket boosters. A half-inch vidicon was chosen for this application because it could readily be made rugged; it represented a minimum of deflection coil weight; and it permitted the use of smaller and lighter optical elements. The circuitry for the entire camera was packaged on two circular printed-circuit boards to conform to the instrument package configuration. It also featured a rigid sandwich construction of glass-epoxy board foam mounted on an aluminum plate and coated with and epoxy conformal coating. This design was able to withstand a high level of vibration and shock. The use of this metal-foam sandwich also successfully solved the problem of heat transfer. The conformal coating was very effective in improving the paths for heat conduction, as well as acting as a binding medium, firmly securing all components to the board.

Simplicity Achieved

Simplicity and high reliability in the JPL camera design was achieved by the use of transistors with negative-feedback circuits. In the video amplifier, where gain stability is very important, DC-coupled complementary pairs, AC-coupled to the following pair, were used. Each pair employed negative feedback as well as circuitry for stabilization of the operating point. Since passage of very low frequencies was required, a clamp circuit for restoring the DC component was used. Special circuit-design techniques were also required in the DC converter (which provided vidicon electrode voltages), the focus current regulator, and the highly linear deflection circuits to insure stable operation during thermal fluctuations.

The fabrication methods employed and the end use of this camera are typical of the design approach which will be used in applying television to the exploration of space. The lunar exploration preceding a soft landing, and following a near-miss trajectory, will be a retarded impact. A television camera designed for such a mis-

sion will be equally adaptable to other planetary flights. The obtainable surface resolution with a given television system is directly proportional to the weight of the optics, which are, in turn, payload limited. Our largest telescopes to date have yielded resolution of the order of 300 meters on the lunar surface. (In comparison, Lunik III produced images with considerably less resolution from less than one-fifth this viewing distance.) The lower lunar albedo (0.07) and the low contrast ratios of the moon's homogeneous surface tend to reduce the effective definition of the image. As viewed from the earth, the effect of atmospheric boil causes further deterioration.

To achieve the best lunar images ever recorded to date, an impact trajectory in which the camera takes a sequence of pictures as the vehicle approaches the surface has a good chance of success. The number of pictures can be increased if the approach rate to the moon is retarded by a retro-rocket and then the vehicle is allowed to fall freely to the surface under the influence of the moon's gravitational field. With this approach, a camera using short-focal-length optics, well within the weight limitations of the payload, can take advantage of the reduction in object distance to produce pictures with very high surface resolution.

On missions using an impact trajectory, and particularly on those for which a soft landing is planned, terminal guidance and the information for controlling the trajectory can be furnished by a television camera similar to ones discussed here. Lateral velocity vectors can be derived from camera images, providing both speed and direction information. Identifiable landmarks, spotted in successive pictures coupled with altitude information, will supply the controller on the earth with the data necessary to execute a suitable landing. This information can also be used as an input to a closed-loop servosystem in the vehicle to control the several phases of a soft landing. In the initial phase, large-area images will furnish information from large distances on the geographical area being approached. As the vehicle approaches the surface more closely, selection of the landing spot can be controlled on the basis of pictorial information showing possible craters or boulders which should be avoided or smooth areas which would be desirable.

The same television camera, with some minor changes to allow for differences in illumination conditions, can be used to monitor the interior of a space cabin to observe animal or human occupants. While the television images of the earth, moon, and planets utilize solar illumination, the interior of a space cabin may well require pulsed artificial lighting as a means of conserving power. In televising human subjects, some restrictions on the brightness, rate, and duration of light flashes must be imposed. The camera will permit aeromedical personnel to study the facial expression of the space-cabin occupant, the condition of his eyes, and his response to stimuli by watching these reactions on earth-based monitors. Subjective observations such as these are particularly useful in judging the general condition and alertness of the occupant.

Because of the rapid change of events in response to space stimuli, it may be desirable to modify the camera design to decrease the frametime to about 1/10 sec or, if slow scanning is retained, to alternate between two shuttered cameras. If the frametime is reduced, changes in the bandwidth and increase in communications power naturally would follow.

An alternative way to save bandwidth is to sacrifice resolution by reducing the number of scanning lines.

Satisfactory pictures could still be obtained with a reduction to 160 lines per frame. In this case, high scene detail could be retained by using a smaller field of view, encompassing, for instance, only the face of the subject. The face and the complete upper torso could be viewed alternately by switching in appropriate optical systems. To achieve the proper scene illumination, a 25-watt lamp with a 100-lumen per watt efficiency would sufficiently illuminate 25 sq ft of scene area from a distance of 3 to 4 ft, providing a highlight brightness of 75 ft-lamberts. This amount of scene brightness is sufficient to activate a vidicon camera which has been shuttered to prevent image smear.

Because of the short distance between the camera and the cabin occupant, the depth of field must be taken into account. This is defined as a range of object distance from the camera at which the images will not be degraded because of misfocus. Since the permissible depth of field varies with lens aperture, compromises must be made with exposure factors such as shutter and over-all scene illumination.

Weather surveying, lunar or planetary reconnaissance, and space-cabin monitoring illustrate the wide range of applications for the basic miniature vidicon camera with appropriate scanning modifications and optical systems. For the present and near future, these and other applications pointed out in the introduction—stellar observations, planetary mapping and exploration, and scientific instrumentation—are all attainable through high-definition television at a minimum tax on power-supply and communication systems. Improvements in vidicons and other image sensors, and in associated circuits and focusing and deflection components, promise an increase in resolution of about three to one.

Camera potentialities will also be increased for space applications by developments in infrared sensitive vidicons, storage vidicons, and electrostatic storage tape. The importance of infrared in astronomical measurements, and in weather observations, where it adds the possibility of both day and night observations of the earth's cloud cover by imaging infrared wavelength emissions, is well established. The storage vidicons possess the characteristic of storing an exposure for a period of several weeks without observable image deterioration. This suggests the possibility of remote viewing and delayed readout. The electrostatic tape, an elongated vidicon photoconductor capable of being rolled on a reel and readout by a television scanning process, is similar in performance to the storage vidicon. This device will be particularly useful for strip photography. In remote planetary picture taking, it will allow images to be stored until the space vehicle is in a favorable place for optimum communication with the earth.

The minature television camera is now in a position to provide a substantial contribution to space instrumentation, and an increased usefulness in space exploration is predicted for the existing design and for image sensors now under development.

Suggested Additional Reading

Hutter, E. C., Moore, T. H., and Inslee, J. A., "Electrostatic Imaging and Recording," *Journal of the SMPTE*, vol. 69, no. 1, Jan. 1960.

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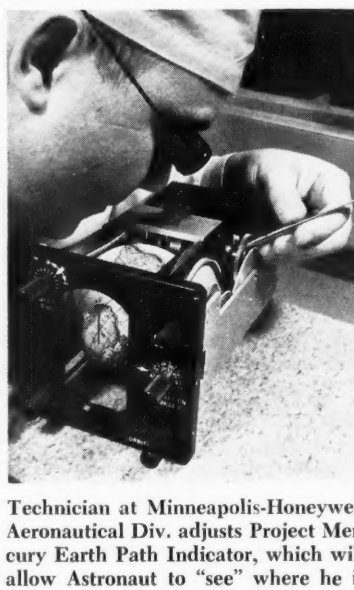
Shelton, C. T., and Stewart, H. W., "Pickup Tube Performance with Slow Scanning Rates," *Journal of the SMPTE*, vol. 67, no. 7, July 1958.

"Space Handbook; Astronautics and Its Applications," Staff Report. United States Government Printing Office.

Spaulding, S., and Staniszewski J., "Television Observations of Occupant Behavior in Space Vehicles," Space Medicine Electronics Symposium, The Franklin Institute, May 18, 1959.

♦♦

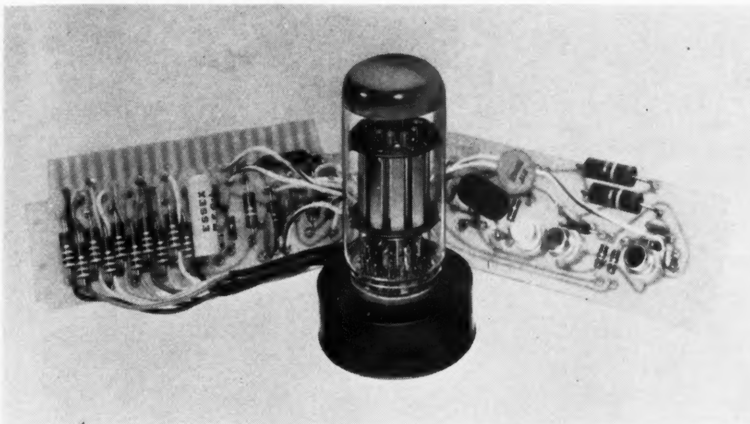
Project Mercury Earth Path Indicator



Technician at Minneapolis-Honeywell Aeronautical Div. adjusts Project Mercury Earth Path Indicator, which will allow Astronaut to "see" where he is over the earth at all times. The Astronaut will view a grapefruit-size replica of earth through the instrument's window (lower left) in the same manner as though he were actually seeing the earth through a window in the capsule.

New equipment and processes

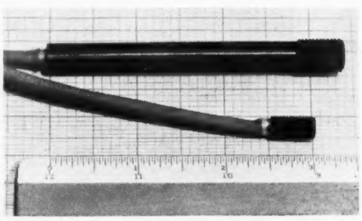
Advance in Electronic Switching



Above, Beam-X switch with transistor circuitry for counting applications to frequencies of 110 kc. Ten electrical outputs activate visual displays, printers, and preset counting functions. The entire unit uses only 56 components, which compares well with some 145 needed in a comparable all-transistor counter.

Burroughs Corp.'s Electronic Tube Div. has developed a new decimal electronic "Beam-X" switch that it expects to effect a major change in basic electronic design logic from binary to decimal systems. The Beam-X switch uses small rod magnets within a vacuum to control the position of an electron beam to any one of 10 output positions. The result is a decimal switch that in size, weight, cost, and power outperforms, according to the company, all existing vacuum, magnetic, and solid-state devices in multiposition switching, counting, distributing, multiplexing, and allied operations. In a typical ten-position switching application, the new Beam-X decimal switch eliminates some 90 transistors, diodes, and resistors which must be used with binary logic to achieve the same results. The new switch appears to have many applications in the missile and space field—e.g., multiplexing flight-data samplers, countdown marking and display, counting and timing for tracking radars, etc.

Temperature Sensor: This Delta-Couple (Model B1) is available with body materials of 1020, ASTM-A7, 4130, or 303-stainless steel; junction material is Chromelalumel. Body



lengths are in $^1/_8$-in. increments from $^1/_4$ in. to $3^1/_2$ in; thermocouple junction location, in increments of $^1/_8$ in. from 0.001 in. of heated surface to 0.005 in. from unheated surface. Advanced Technology Laboratories, Div. of American-Standard, 369 Whisman Rd., Mountain View, Calif.

Vibration Testing: When a random shaker system is equalized at a low sine wave level, the system cannot be assumed linear while the test is in progress. These unknown variations can be analyzed and corrected by use of the ESD-20 spectral density equalizer and ASD-20 spectral density analyzer, featuring simplified controls, continuous analysis, and immediate adjustment. Ling Electronics Div., 1515 S. Manchester Ave., Anaheim, Calif.

Thermatool—High-Frequency Welding

Fins, ribs, and other continuous projections can be produced at high speeds on ferrous and nonferrous tubes and flats by the Thermatool high-frequency welding method developed and patented by the New Rochelle Tool Corp., New Rochelle, N. Y.

In the Thermatool method, the edges of the metal to be bonded are positioned opposite each other as the strip to be added travels through a

Welding a fin to a tube with Thermatool.

forming mill (for tubing, any standard mill), the open seam being kept in the from of an elongated V, with the root of the V at the squeeze rolls which effect the weld. Two sliding contacts riding on either side of the open seam, about 1 or 2 in. from the root, introduce high-frequency (450,000 cps) current into the metal. This current hugs the edges, producing high local heating. Pressure applied at the root of the V then will give a forged weld, forged lap, mashed lap, or butt edge, as desired.

This technique makes possible the welding of strip to tubing, as well as innumerable odd combinations. The same welding head can be used interchangeably with various metals and alloys to weld continuously in thicknesses from 0.004 to $^3/_8$ in. at speeds up to 1000 fpm.

The accompanying picture shows a closeup into a compartment where a fin weld is being made. Argon gas enters the compartment through the doughnut-shaped chamber. Behind this doughnut, the squeeze roll effects a weld between fin and tube. Just behind the squeeze roll can be seen the two sliding contacts that introduce 450,000-cps current into the metal. ♦♦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